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HEALTH PHYSICS MANUAL
of
NRTS AREAS OPERATED BY
IDAHO NUCLEAR CORPORATION

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IDAHO NUCLEAR CORPORATION

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ABSTRACT

This manual is designed to help Health Physics personnel familiarize themselves with the Idaho Nuclear Corporation's operated NRTS areas in which they are training or working. A general description is given of the specific plants and areas emphasizing radiation hazards and safety procedures.

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CHAPTER I

INTRODUCTION TO PRINCIPLES OF REACTORS

The purpose of this chapter is to acquaint the HP with the general physical concepts of what is required to make a reactor work and to indicate some of the ways in which it can be done.

Nuclear reactors liberate and control nuclear energy. Presently this process is limited to the containment and control of the fissioning of unstable nuclei of high mass numbers.

The nuclei most commonly used are those of U-235, P-239, and U-233 in that order. Several other isotopes have fissionable nuclei, but they are not commonly used. The reasons for not using these isotopes are numerous, and they are beyond the scope of this discussion.

A. The Fission Process

Following is a simplified discussion of the fission process. Certain nuclei upon the absorption of a neutron are more apt to split into two nuclei of lower mass number than they are to increase in atomic weight. That is

$$U^{235} + n^{1} \rightarrow X^{95} + Y^{139} + 2n^{1} \qquad (1)$$

occurs more frequently than does

$$U^{235} + n^{1} \rightarrow U^{236} + \gamma \qquad (2)$$

In equation (1) there is a loss of mass during the transition. The energy liberated during the fission process can be determined using Einstein's equation

$$E = mc^{2} \qquad (3)$$

It is convenient to express m in a.m.u. (atomic mass units).

$$E\ (\text{MeV}) = m\ (\text{a.m.u.}) \times 931$$

since 1 a.m.u. is equivalent to 931 MeV.

Consider a possible fission event:

$U^{235} + n^{1} \rightarrow X^{95} + Y^{139} + 2n^{1}$ Mass of X^{95} = 94.945 a.m.u.

Mass of U^{235} = 235.124 a.m.u. Mass of Y^{139} = 138.955 a.m.u.

Mass of n^{1} = 1.009 a.m.u. Mass of $2n^{1}$ = 2.018 a.m.u.

Total mass = 236.133 a.m.u. Total mass = 235.918 a.m.u.

Difference: 236.133 a.m.u. — 235.918 a.m.u. = 0.215 a.m.u.

The energy released per fission is, then, (0.215) (931) = 198 MeV.

The total average energy released per fission is 201 ± 6 MeV. This value is experimentally determined. The following table gives a breakdown of the distribution of this energy.

TABLE I

Distribution of Fission Energy[1]

	MeV
Kinetic energy of fission fragments	168 ± 5
Instantaneous gamma-ray energy	5 ± 1
Kinetic energy of fission neutrons	5 ± 0.5
Beta particles from fission products	7 ± 1
Gamma rays from fission products	6 ± 1
Neutrinos	~ 10
Total	201 ± 6

The 10 MeV given off as neutrinos are lost from the system. The amount of energy lost from the system from gamma rays and neutrons depends on the system. The rest of the energy will be expressed as heat[2].

Fission at the rate of 3.1×10^{10} fissions per second produces one watt of power. If 1 lb. of fissionable material is completely fissioned, it would produce 1.0×10^{7} Kw-hr or "The power production corresponding to the fission of 1 gram of material per day would be roughly 10^{6} watts, i.e., 1 megawatt."[3]. This power potential makes nuclear power desirable, but the nature of the energy released presents problems unique to reactors.

B. Critical Mass

Note in equation (1) that approximately two neutrons were produced during fission. The average neutrons per fission produced is of the order of 2.3 during the fissioning of U-235. To have the fissioning process self-sustaining in a reactor, an average of at least one neutron produced by a fissioning nucleus has to cause another fission. To achieve such a condition, target nuclei have to be arranged in close proximity to a fissioning nucleus such that the probability of at least one of these nuclei being bombarded by a neutron and fissioning is one. The mass of material necessary to provide this condition is known as the Critical Mass. Stated in another way: Critical Mass is the mass of fissionable material necessary to sustain a nuclear chain reaction. This entity, the actual mass of fuel necessary to arrive at criticality, is generally determined by five conditions: (1) type of fuel, (U-235, Pu-239, etc.), (2) percent of fissioning nuclei present, (referred to as enrichment), (3) geometric configuration, (4) neutron moderation, and (5) neutron reflection.

1. Type of fuel

The average number of neutrons liberated for each fissionable isotope is different. The probability of fission occurring differs with each isotope. And the probability of a neutron being captured but not causing fission differs with each fissionable isotope. All three of these fuel characteristics determine the number of target nuclei that must be present if a chain reaction is to be sustained.

2. Percent enrichment

Neutrons are captured by U-238 and other materials which might be present within the fuel. This capture effectively reduces the number of neutrons available for fission. The presence of these materials also decreases the density of the fissionable nuclei. Both conditions demand an over-all increase in the fuel volume if a chain reaction is to be sustained.

3. Geometric configuration

Neutrons will be lost or leak out of the external surface of the fuel. If the ratio of surface area to volume is great, the leakage will be large. If the ratio is reduced, so will the leakage be reduced. As an example, the surface area per unit volume ratio for a sphere is much less than it is for a cube. As leakage is increased so also must the volume of the material be increased to achieve a critical mass. Conversely as the leakage is reduced less volume is needed.

4. Reflection

Materials which scatter or "reflect" neutrons back into the core partially overcome the problem of leakage. Reflector materials are of low mass number so that elastic collisions with the "reflector" nuclei readily occur. Materials having a low neutron capture probability have to be chosen to achieve efficient reflection.

5. Moderation

The probability of neutrons interacting with fissionable nuclei varies with the energy of the neutron. The fission cross sections (interaction probabilities) of U-235, U-233, and Pu-239 are much greater for thermal neutrons than for fast neutrons. Materials having low atomic numbers and low capture cross sections are used to moderate or slow down fast neutrons. Every time a nucleus is hit and scattered, kinetic energy is transferred from the neutrons to the scattered nucleus. After a series of elastic scatterings, the neutron is in thermal equilibrium with its surroundings. It is easily seen that materials which are good moderators are also good reflectors. Neutron efficiency is increased using thermal neutrons, so fewer target nuclei of fissionable material are needed if the percentage of thermal neutrons is increased.

C. Reactor Power Level

The rate at which fission occurs determines the power level of a reactor. As previously stated, 3.1×10^{10} fissions per second produces one watt of power. A reactor which is just critical produces just a few fissions per second. To arrive at some power level conditions have to be altered so that, on the average, just slightly more than one of the neutrons released during each fission causes another fission. This will effect an increase in fission rate. When the desired power level is reached, conditions are changed so that there is just one neutron produced per fission causing fission and a steady state power level is maintained. These required conditions can be expressed in terms of the necessary quantity called the effective multiplication factor, (K_{eff}). K_{eff} is defined as the ratio of the average number of neutrons causing fission to the number of neutrons required to sustain a chain reaction. Therefore one fission produced neutron per fission causing fission is expressed as $K_{eff} = 1$. The number of neutrons causing fission in excess of the number required to maintain a nuclear chain is expressed as K_{ex}. This is one of the factors determining the rate at which power will increase in a reactor. Neutrons remain a finite time in a reactor if not captured. This is called "life time". Therefore the life time of a neutron also determines the effectiveness of that neutron.

Mathematically, the change in the number of neutrons in the reactor per unit time is

$$dn/dt = n\ (K_{ex}/L) \tag{4}$$

where n = number of neutrons

t = time

K_{ex} = as defined above

L = the average neutron life time.

or

$$dn/n = (K_{ex}/L)\ dt. \tag{5}$$

Integrate both sides and impose the condition that

$$n = n_o \text{ at } t = 0$$

then

$$n = n_o\ e^t\ (K_{ex}/L). \tag{6a}$$

The number of neutrons present within the reactor at any one instant is proportional to the number of fissions occurring per unit time, and is therefore proportional to the reactor power level. In equation (6a) when $K_{ex} = 0$ and $n = n_o$, the reactor power remains constant, or in other words, the number of neutrons (neutron flux) within the reactor remains constant. If K_{ex} is very small in comparison to L, reactor power slowly increases. If K_{ex}/L is not small, a rapid power increase can result in an out-of-control super critical condition.

The average neutron life time (L) per K_{ex} (L/K_{ex}) is called the reactor period. Now equation (6a) becomes

$$N = N_o e^{t/T}. \qquad (6b)$$

Frequently reactor control is expressed in terms of reactor period. A short reactor period results in a fast power rise and a long reactor period results in a slow power rise.

The means of reactor control are the insertion or withdrawal of additional (1) fuel, (2) poison, (3) reflector or (4) moderator. These will be discussed in the next section.

Reactor power can be measured by determining the heat output of the reactor and/or by the measurement of the neutron flux. The systems used to obtain this information vary with the different reactors and their types.

D. General Reactor Components and Control

The general components of any reactor can be broken down into six categories, (1) fuel, (2) moderator, (3) reflector, (4) control, (5) coolant, and (6) shielding.

1. Fuel

U-235 in varying degrees of enrichment with U-238 is used as fuel. Many power and Pu-239 production reactors use natural uranium which contains 0.71% U-235 and about 99% U-238. Other reactors use enrichments up to 96% U-235 and 4% U-238. Test reactors usually use this highly enriched fuel load. The fuel elements are usually clad in aluminum, stainless steel, ceramic, graphite, or zircaloy. These elements come in various shapes and sizes dictated by the design and purpose of the reactor in which they are used. Pu-239 in varying degrees of enrichment with U-238 can be used much as U-235. U-233 enriched Th-232 can also be used. The use of each fuel type requires different conditions.

2. Moderators

There are four elements which enjoy regal status as moderators. Others can be used with some degree of success but these have proven to be the best. They are carbon in the form of graphite or an organic, beryllium in its metallic or oxide form, hydrogen as a hydride, organic or water, and its close relative deuterium as a hydride, organic or water. Deuterium, due to its high cost and difficulty in handling, is usually used only in the form of water. These materials are also used as reflectors.

3. Reflectors

In addition to the above mentioned materials, other materials such as aluminum, zirconium, magnesium, silicon, etc. have some reflection properties.

4. Control

Reactor control is effected by controlling those parameters associated with the determination of a critical mass. That is, the introduction or removal of fuel, moderator, and/or reflector is used to control the neutron flux within a reactor. To these three parameters is added a fourth parameter, neutron "poisons". Any combination of these four parameters might be used in reactor control. A neutron poison is any non-fissionable material such as xenon, cadmium, boron and lithium having high absorption cross sections. These materials are "black" to thermal neutrons. Xenon as a fission product is a natural damper on a reactor markedly limiting the steady state power levels of most natural uranium reactors. It also reduces the efficiency of all thermal neutron reactors. Cadmium is frequently used in control rods. Fine control can be achieved with its use. Boron is used as a burnable control mechanism. As fuel is depleted, so is boron. By combining fuel and boron, control is built into a system.

5. Coolant

Most of the kinetic energy of the emission resulting from fission reverts to heat in the system. In a power reactor the heat is utilized to produce electricity. In all reactors heat must be removed from the reactor core and the reactor structure. There is no limit to the temperatures that a reactor could attain without cooling if the reactor components could withstand the temperatures imposed upon them. Reactor cores have been known to melt down and destroy themselves because of inadequate heat removal. Transfer of heat from a reactor to some medium which transfers energy to a heat sink or acts itself as a heat sink is needed. Gases and liquids, primarily, are used as coolants. Water and organic liquids make good coolants as well as moderators. Liquid metals such as sodium, potassium, a combination of both called NaK, and mercury have been used as coolants. Many of the first reactors built used air as a coolant. Nitrogen and helium have also been used extensively. Gases and liquid metals are primarily coolants since they do not appreciably moderate neutrons or absorb them.

6. Shielding

A minimum of three types of shielding is necessary for reactor shielding. These are neutron, gamma, and thermal shielding.

Neutrons and gamma rays are not completely divested of their kinetic energy within a reactor core. There is extensive leakage of both from the core. It is necessary to provide protection for personnel working around the reactor. Shielding is therefore necessary to provide this protection. The requirements for shielding neutrons differ from those for shielding gamma rays. Neutrons are thermalized and then captured by using moderators and neutron poisons. Gamma ray shielding requires high density materials such as iron or lead to attenuate gamma photons. In addition to neutron and gamma shielding, thermal shielding is necessary, not only for personnel protection, but also for the protection of surrounding materials from undue thermal stresses.

In addition to personnel protection from these types of radiation, the protection of delicate instrumentation from radiation damage is necessary. A reactor is often surrounded with a large number of instruments which are easily damaged or their readouts distorted by high radiation fields.

E. Specific Problems

As a result of a reactor's unique system, some of the problems associated with a reactor are unique. A few of the major problems will be briefly discussed here.

1. Fission Breaks

A fission break is the result of cladding failure of a fuel element or rupture of an experimental fuel capsule which introduces fission products into the cooling system. A severe fission break can release many curies of activity to the stack and contaminate the cooling system. A fission break can be detected by several methods. The methods to be used depend upon the type of reactor.

2. Fission Product Poisoning

The continual production of fission products gradually reduces the efficiency of a reactor. These fission products usually reduce the neutron efficiency below the compensating factors of control long before all of the reactor fuel is burned up. Reactor fuel has to be reprocessed many times before it can be fully utilized. Xe-135 and Sm-149 are the most devastating of the fission product poisons.

3. Material Changes

Materials are affected by radiation. Neutron bombardment produces impurities with materials such as

$$Al^{27} + n^{1} \rightarrow Al^{28} + \gamma \rightarrow Si^{28} + \beta + \gamma. \qquad (7)$$

Gamma radiation and thermal radiations change crystal structure and create high thermal stresses which distort and change reactor components. They also cause the breakdown of some chemical bonds and the forming of others. Materials thus changed in a reactor are referred to as corrosion products.

4. Heat Removal

Normally heat has only to be removed from the source of radiation and its immediate surroundings in power developing units using conventional fuels. In a reactor it is necessary to remove heat from the neutron and gamma shielding as well. In some instances this requires a separate cooling system for reactor shielding.

5. Chemical and Metallurgical

Uses for uncommon metals are frequently found in present day reactors. Some of these materials have unusual metallurgical properties which make them hard to work with. Many of them are highly pyrophoric. Others are hard to work with chemically, and some are readily attacked by materials used for moderation and cooling. Sometimes corrosion products produce chemical difficulties within a reactor and means have to be provided for their removal. Leakage of fission products into reactor coolant or moderator can produce radicals which are damaging to reactor structure. These also have to be removed to maintain good operation. Ion exchange columns are frequently used to reduce the amount of undesirable chemicals formed in an operating reactor.

At times the close proximity of materials which are dangerous when combined is necessary in a reactor. An example of this is the association of water and liquid metals, such as sodium, potassium, or NaK, these being used for heat transfer and/or moderator. No leakage between systems can be allowed or an explosion will result.

There are many more reactor associated problems of interest which are beyond the scope of this discussion.

Following is a list of several of the more common materials found in reactors and their uses. The extent of usage is a function of a specific reactor design.

MATERIAL	USES
Water	Moderator, reflector, coolant, and shielding
Graphite	Moderator and reflector
Beryllium	Moderator, reflector, and photo-neutron producer
Aluminum	Structure, fuel cladding, reflector, and shielding
Iron, Steel	Structure, fuel cladding, and shielding
Liquid Metals	Coolant
Gases	Coolant
Lead	Gamma radiation shielding
Concrete	Structure, moderator, reflector, shielding
Cadmium, Boron	Control (poisons) neutron shielding in connection with moderators
Paraffin	Neutron shielding, moderator
Plastics	Neutron shielding, moderator
Liquid Organics	Moderator, reflector, coolant, shielding
Ceramics	Fuel cladding
Zircaloy	Fuel cladding
Uranium	Fuel, shielding
Plutonium	Fuel

F. Reactor Types

There are many ways in which individual reactors differ. Certain characteristics are common to all reactors and these have been discussed. Following is a list of four existing general reactor types and their general characteristics.

Reactor Type	General Characteristics
1. Piles	a. Graphite moderated, or D_2O moderated b. Large critical mass (low enrichment or natural U) c. Large internal efficiency for thermal neutrons d. Thermal neutron reactors only e. Gas, liquid metal, or water cooled f. Poison controlled g. Limited in power by size and xenon poisoning

Reactor Type	General Characteristics
2. Homogeneous Reactors (all others are heterogeneous reactors)	a. Fuel is utilized in a liquid solution, the solvent usually acting as the moderator b. High enrichment c. Cooled by coils running through solution or running parts of the solution through heat exchangers d. Difficulty in cooling limits power e. Absolutely no system leaks can be tolerated f. Expensive construction g. Difficult and expensive shielding h. It was hoped that fission products could be removed continuously to achieve more efficient fuel burnup
3. Tank Types	a. Natural Uranium or enriched fuels (enriched fuel being more commonly used) b. Cooled by water, gas, liquid metals, or organics c. Versatility of power output d. Versatility of available neutron flux or fission production for experimentation e. Comparatively cheap construction
4. Swimming Pool Reactors	a. Enriched fuel elements b. Water cooled, moderated and shielded c. Zero to low power due to radiation hazard and limited cooling d. Cheap construction e. Usually used for reactivity measurement facilities

Note: Of the four basic structural designs mentioned, tank type reactors are the only kind that lend themselves to fast neutron reactor development.

CHAPTER II

MATERIALS TESTING REACTOR

A. The Fundamentals of MTR Operations

The Materials Testing Reactor was designed and constructed for the express purpose of facilitating the conception and design of future reactors.

Aside from those highly urgent and immediately practical problems related to testing reactor components, there were many fundamental experimental studies in the high flux regions that were to be carried out in the MTR. The high density of epithermal neutrons in the MTR permitted the extension of the practical range of the crystal spectrometer to higher neutron energy ranges. The properties of fissionable isotopes in the lower-resonance energy regions could be investigated and their nuclear constants more accurately determined. Reactions of higher order (the capture of two or more neutrons in succession by the same nucleus) could now produce significant quantities of rare isotopes, thereby permitting the study of their nuclear constants.

Production of radioisotopes in amounts and of specific activities heretofore not readily available was initiated.

The MTR was designed with numerous experimental facilities which permitted the irradiation of materials used for reactor components, fuel assemblies, coolants, moderators, and reflectors. Tests are carried on under simulated operating conditions of temperature, pressure, and environmental factors.

The MTR is a heterogeneous reactor, light water cooled and moderated, which uses beryllium and graphite as a reflector. The fuel assemblies are plate-type and are fabricated from aluminum.

The MTR and its many experiments constitute so complex an assembly that equipment failures and component malfunctions can be expected periodically. Some of these could jeopardize the reactor or a potentially dangerous experiment; therefore, safety circuits are incorporated to shut the reactor down.

1. Reactor Building

The reactor building is designed to enclose the reactor structure and the canal and to furnish space for experimental facilities on the main floor level and in the basement. In addition, two balconies above the main floor incorporate the control room, a room to house the electrical equipment, and Operations' personnel offices.

The building was designed to operate at a positive pressure of 1-1/2 in. of water to reduce entrance of dust into the building, but due to building additions and increased usage of ventilating air, atmospheric pressure now prevails.

Building air is drawn through filters into the reactor structure and used to cool the graphite reflector. The building also incorporates pre-cast insulated concrete slabs which are bolted to the concrete encased structural columns to form the walls. They are designed to be blown outward in the event of a high pressure surge in the building. The flat roof is constructed of pre-cast concrete panels laid on steel purlins covered with foam-glass insulating blocks and built-up roofing.

The main floor of the reactor building is reinforced concrete 130 ft. sq. The floor area immediately surrounding the reactor structure is 3 ft. thick; and surrounding this area and extending to the building wall, the floor is 12 in. thick. The basement floor is also reinforced concrete, 12 in. thick. The balcony floors are generally 4 in. thick reinforced concrete.

Each corner of the reactor building contains stairways leading from the basement. Those on the west side are extended to serve the balconies also. At the northwest corner of the building, a passenger elevator serves the basement, main floor, first balcony, and second balcony. On the west side of the building, a freight elevator serves the reactor building basement, the reactor wing building basement, the main floor of the reactor building, and the reactor wing building.

2. Overhead Cranes

Two overhead cranes are used in the reactor building. The largest is a compound bridge and trolley type crane with two hooks of 30 ton and 5 ton capacity, respectively. It is used to lift off the reactor top plug with the drives and to move the heavy casks used to transport radioactive fuel, etc.

The smaller crane is also a bridge and trolley type but of 1000 lb. capacity. It is positioned directly over the reactor vessel and is used during reactor shutdown for handling tools, core components, etc.

Heavy tools used in the tank are generally handled by means of a nylon rope and pulley combination which gives a 2 to 1 mechanical advantage. The smaller crane block is raised to a spot just short of the upper limit switch. Then tools can be inserted or removed by manual manipulation of the rope.

3. Reactor Vessel

The MTR reactor vessel is made up of five individual tanks. The five tanks join together to form the completed vessel about 30 ft. in height.

The "A" tank which is the uppermost tank is fabricated of stainless steel, has an ID of 71 in., a height of 11 ft. 7-3/4 in., and is permanently set in the concrete biological shield. The top flange is flush with the top of the shield structure; and the top flat head, called the top plug, was originally mounted directly on this flange.

Placing reactor experiments directly in the active lattice or beryllium reflector, i.e., "in-pile" experiments, called for significant numbers of nozzles opening directly into the vessel. This requirement was met by the installation of an extension spool mounted directly on the top of "A" tank. The reactor top plug is now mounted on this extension.

The "A" tank extension is fabricated of stainless steel and has an ID the same as "A" tank. It is 18 in. in height and incorporates thirty-six 2-1/2 in. ID nozzles inclined 50 degrees from the vertical, equally spaced around its periphery. Blind flanges fitted with tube sealing glands allow installation of instrumentation leads connected to the in-pile experiments.

A clearance is required between the outside diameter of the reactor top plug and the tank wall for ease of handling. To prevent radiation from streaming through this annulus, a heavy inner shielding ring rests on the stainless steel ring attached to the "A" tank wall. A similar ring was installed outside the tank to reduce streaming in that annular zone.

"B" tank is attached to the top face of the bottom flange of "A" tank and serves, by means of a bellows section, as an expansion joint between "A" and "E" tanks which are permanently fixed in the concrete structure. This tank is made of stainless steel, is about 2 ft. 2 in. in height, has an ID of 54-1/4 in., and is located in elevation just above the top steel thermal shield plates surrounding the graphite reflector. "B", "C", and "D" tanks were designed to be removable through "A" tank in case of gasket failure, tank failure, or other reasons.

"C" tank is fabricated of aluminum, has an ID of 54-1/4 in. and a height of about 51-1/2 in. This tank is in the upper part of the "pebble" zone of the graphite reflector.

"D" tank surrounds the reactor active lattice and beryllium reflector. It is aluminum and has the same ID as "C" and "B" tanks. Its height is about 6 feet. The wall thickness is one inch except for the middle where it is 1-1/4 in. thick in the vicinity of the HB thimble penetrations of the tank. "D" tank was designed to provide the strength required to sustain the coolant water pressure and to support the weight of the core assembly. It was made as thin as possible so that neutron absorption would be minimized.

The bottom tank making up the complete reactor vessel is "E" tank. This tank is about 6 ft. 4-1/2 in. long and was supported initially by the structural steel which also supported "A" tank. Both "A" and "E" tanks were given a coat of tar and embedded in the concrete biological shield.

4. Graphite Reflector

The function of the graphite reflector surrounding the reactor and vessel is to thermalize and reflect neutrons back into the core active lattice and to contain thermalized neutrons in a zone large enough to allow the placement of numerous experimental facilities. The reflector extends vertically from an elevation near the top of "E" tank, past "D" tank, and covers about the lower two-thirds of "C" tank, for a total height of 9 ft. 4 in. The horizontal dimensions are 12 ft. north to south by 15 ft. east to west.

A graphite pebble zone extends from the reactor wall out to the inside edge of the permanent graphite. This zone is 7 ft. 4 in. square and is filled with approximately 700,000 one inch diameter graphite balls. These balls may be drained through pipes to storage bins allowing either the replacement of the balls or the replacement of the "B", "C", or "D" tanks. Some experimental facility liners penetrate the ball graphite zone.

Surrounding the graphite ball, or pebble zone, is the solid graphite reflector. This mass is composed primarily of 4 in. by 4 in. graphite bars which extend from the pebble zone outward to the inner face of the steel thermal shield.

The cooling air enters the graphite reflector from the space between the lower thermal shield plates, flows vertically upward, and then out exit air ducts embedded in the concrete shield.

5. Thermal Shield

Heavy steel plates form a thermal shield surrounding the graphite reflector to reduce the heating of the biological shield due to radiation from the core. This shield consists of two 4 in. thick plates placed on all six sides of the reflector. Air ducts running from filters located on all four faces of the biological shield near the reactor structure top furnish cooling air to the thermal shield. The air flow enters the space between the side plates, flows downward into the space between the two bottom plates and turns upward to cool the graphite reflector. The air is collected in a space below the top shields and above the graphite and flows into ducts which carry it to an external stack.

6. Biological Shields

The biological shield surrounding the reactor vessel and the graphite reflector is, as its name implies, a barrier placed between the high radiation flux surrounding the reactor core and the areas to be inhabited by personnel. This high density (approximately 3.2 Specific Gravity) barytes concrete shield extends from the top of "A" tank to a point below the basement floor.

The external surfaces of the biological shield are formed by steel plates 1/2 in. thick above the first floor and 3/4 in. thick in the basement. The cubicles and face plates of the beam holes and other facilities are welded integral with these forms which supply a convenient and substantial support. The permanent facility liners extend from the face plate to an inner steel form surrounding the thermal shield. The experimental facility hole liners extending through the thermal shield and the graphite reflector are fabricated of aluminum and could be replaced.

7. Top Plug

The top plug of the reactor vessel serves as a top sealing head and as a base upon which the drive mechanisms for the shim-safety and regulating rods are mounted. The plug is in the shape of a built-up flat head about 10-3/4 in. thick. The top plate, 2-1/4 in. thick, and the bottom plate, 1/2 in. thick, are separated by an exterior cylindrical shell and spacers 1 in. thick as well as by heavy wall tubes through which the drive rods pass. The space enclosed by these plates is filled with lead shot for biological shielding purposes. Except for the shot, the top plug is made of stainless steel. The bottom surface of the top plug flange seats against a square asbestos rope gasket which is recessed partially into the top flange of the "A" tank extension. Fifty-two bolts, 1-1/3 in. in diameter, are used in attaching the plug to the vessel.

In addition to the drive rod penetrations, two large manholes, 18-1/2 in. in diameter, are furnished on the east and west sides. While manhole covers constructed similarly to the top plug were originally used in these holes, one cover has since been fabricated and installed on the west side which incorporates a glass viewing port. The core can thus be viewed during reactor operation. A second manhole cover has been provided with an underwater light to supply additional light inside the reactor during low power operation.

The top plug incorporates two electric cable junction boxes mounted on the drive platform, one on the north and the other on the south. These boxes include multi-contact receptacles, one for each shim-safety and regulating rod. When the top plug is in place on the reactor, the electrical connections and signal connections are brought to the plug on hinged supporting arms called "semaphores". For removal of the top plug to dry dock, the cables are disconnected at the junction boxes and the semaphores are dropped to a vertical position on the sides of the north and south reactor instrument cubicles. Here they may be connected to cables which serve the top plug while in dry dock.

Four bases for the pipe stanchions used to support the drive mechanism platform are fabricated on the top surface of the top plug. Similarly, four lugs for connection to the lifting bail are also included. The building crane lifts the top plug by means of the lifting bail.

Attached to the bottom of the plug are the four stanchions which support the spider assembly. When the "A" tank extension was installed on the reactor vessel, this increased the distance from the top plug to the core. Extensions were added to the shim-safety rod, drive rods, the regulating rods, and to the spider support stanchions. The extension to the stanchions maintained the distance from the bottom spider to the core as originally designed but increased the unsupported length of the drive rods. This length might have resulted in increased vibration in the rods due to the water flow; so an intermediate spider similar to the original was fabricated and installed at a point between the top plug and original spider.

8. Bottom Plug

The reactor vessel bottom plug is similar to the top plug. The bottom sheet is 2-1/2 in. thick stainless steel, the top is 1-1/4 in. thick, and the total thickness is 20-1/2 in. The intervening space is filled with lead shot for shielding purposes. The top surface of the plug flange is grooved to fit an aluminum ring gasket and bolts on the lower flange of "E" tank.

The shim-safety rod shock absorbers are mounted on the top surface of the bottom plug. Small diameter plugs are installed beneath each shock absorber body in the bottom plug and include a tube to flow water continuously through the absorber into the vessel. By measuring the individual flow of the water into the absorber bodies, the reactor operator can tell if the rods are seated in the absorbers.

Thirty-seven monitor tubes are installed in the bottom plug and extend vertically upward to a point inside the individual fuel assembly lower end boxes. The tubes incorporate: (1) a thermocouple to measure the fuel assembly coolant temperature, (2) a pitot tube to measure the coolant flow, and (3) a sample tube, which is used to draw off samples of the coolant. These samples are measured for radioactivity. Any excess activity might indicate a rupture in that particular fuel assembly fuel plate cladding. Piping for these monitor tubes runs to the monitor room.

Located below the bottom plug, and mounted to the ceiling of the sub-pile room, are two barytes shielding doors. These doors were designed to provide the additional shielding required for personnel access into the sub-pile room during reactor operation. During reactor shutdown, the doors may be rolled away, i.e., to the north and south, to expose the bottom of the bottom plug and its associated piping. The doors are divided on the east-west centerline and include slots for passage of hydraulic rabbit piping, the discharge chute, etc. See Figures 1 and 2.

9. Discharge Chute

Another internal component installed in the reactor vessel is the discharge chute used to discharge spent fuel assemblies, control rods, experimental components, or irradiated slugs. This chute is installed below the beryllium reflector on the east side of the core, and access to it is achieved by removing a large beryllium reflector piece called the "D" piece. The chute is then exposed and is unrestricted except for a shielding plug located at the bottom plug level. This plug serves to shield the hole left in the bottom plug by the discharge chute and is removed and stored in a rack on the spider guide ring prior to use of the discharge mechanism. The discharge chute extends below the bottom plug and is terminated by a hydraulically-operated full-opening valve. The discharge mechanism connects to the discharge chute at this point and allows the transfer of fuel assemblies, etc., to the canal.

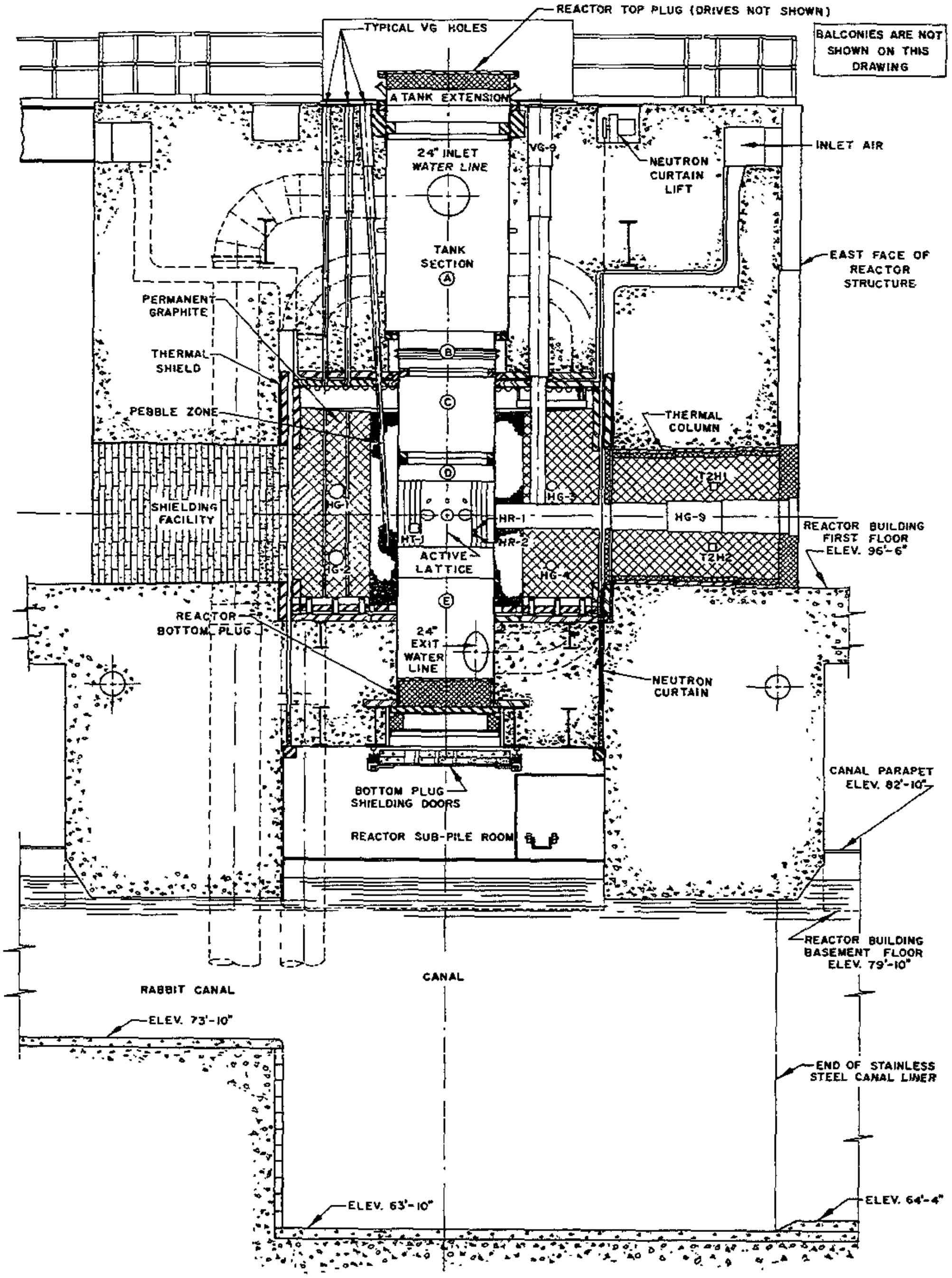


Figure 1

Materials Test Reactor Structure
(Vertical Section Through East-West Centerline Looking North)

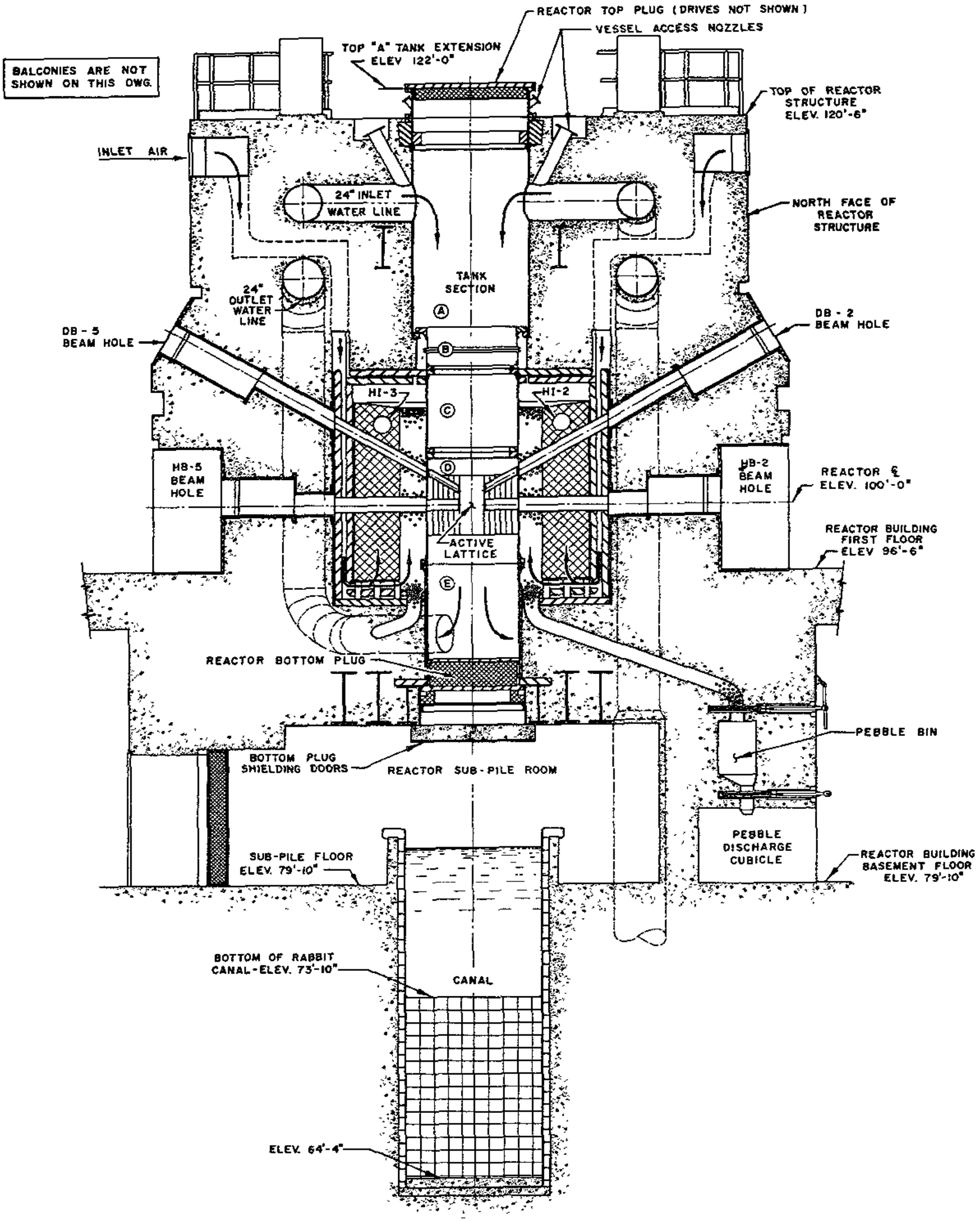


Figure 2

Materials Test Reactor Structure
(Vertical Section Through North-South Centerline Looking West)

10. Tank Internal Structures

The basic functions of the reactor vessel internals are to furnish support to the fuel assemblies and core reflector pieces and to guide the shim-safety and regulating rods. The downward flow of the cooling water through the core generates approximately 40 psig pressure drop. The fuel assemblies and the reflector are supported by the lower support casting. This component is, in turn, supported by a segmented stainless steel ring which is bolted to the bottom face of "D" tank lower flange. The lower support casting has small buttons and spacer bars bolted to it for the majority of reflector pieces to rest on and has circular holes to serve as receptacles for the lower end boxes of the reflector pieces (commonly called "A" pieces). The active lattice of the core is supported on a lower assembly grid which rests in a recess in the center of the lower support casting. This casting also furnishes support for the lower guide grid which is hung from the casting by the lower cradle. The lower guide grid supports the roller bearing assemblies which align the shim-safety rods. All of these components, except the bearing assemblies, are made of a high strength aluminum alloy.

As mentioned before, the beryllium reflector pieces are close fitting and interlocking and do not require a top alignment grid. The only core components requiring top alignment are those in the active lattice. These are the fuel assemblies, the shim-safety rods, and the lattice beryllium pieces called "L" pieces. These latter items are shaped like fuel assemblies, including top and bottom end boxes and fill the lattice positions not occupied by fuel assemblies. These positions are presently the two southern rows of the 5 by 9 lattice array. The upper grid assembly holding the top end boxes of the lattice components is made easily removable in order that the core may be conveniently refueled from above when the top plug is removed (see Figure 3).

A means of supporting the upper grid assembly is necessary since it covers only the area of the 5 by 9 array. Support is furnished by the upper support casting. The casting also serves as a support for bearing assemblies which guide the regulating rods. The two regulating rod positions on the south side of the lattice have been converted to experimental facilities.

Three sub-assemblies form the upper grid assembly located inside the upper support casting "box". The lowest is the upper assembly grid which is positioned just above the lattice fuel assemblies and "L" pieces and contains circular holes to receive the upper end boxes of these components. The top grid of the unit, called the upper guide grid, is also fastened to the grid spacer and supports the bear-grid assembly (upper assembly grid, the grid spacer, upper guide grid, and locking mechanism) and is removed as a unit when work is done in the active lattice. A means of locking this assembly in place is provided by a linkage which is bolted to the north and south inside faces of the upper support casting "box".

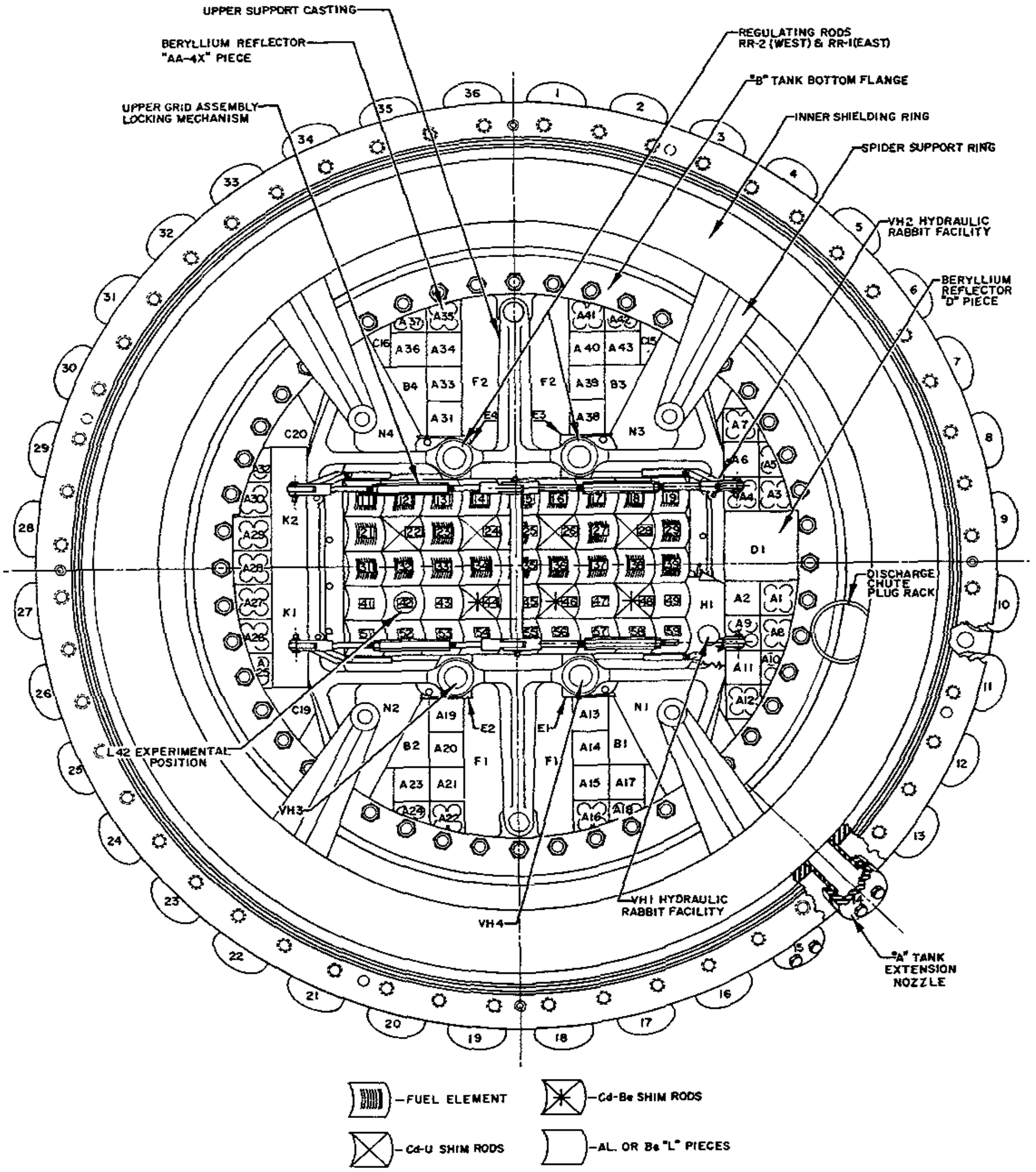


Figure 3

Materials Test Reactor Tanks and Internals
Top Plan with Top Plug Removed

Since the shim-safety and regulating rods are driven from the top plug, a means is required for connecting them to the drive rods which project into the vessel through the top plug. The top of the shim-safety rod has an iron armature which couples to an electromagnet attached to the bottom of the drive rod. The regulating rod connection is a simple threaded drawbolt joint.

11. Reactor Core and Reflector

The MTR reactor core and reflector may be visualized as a vertical right cylinder 54 in. in diameter and 39-3/8 in. high. These are the dimensions of the beryllium reflector, which radially fills "D" tank. Centered in this reflector is the active lattice which is the zone that may contain fuel assemblies, control rods or reflector pieces. This active lattice is dimensioned approximately 15.7 in. north to south (five fuel assembly widths) by 28.8 in. east to west (nine fuel assembly widths).

The position of the fuel assemblies in the active lattice is in the three northern rows and consists of 23 assemblies. The seven shim-safety rod positions are in the second and fourth rows of the lattice and are separated by one fuel assembly in all directions in the second row and by beryllium "L" pieces in the fourth row. The three southern shim-safety rods which are surrounded on three sides (the north side excluded) by beryllium reflector pieces are made with a cadmium poison upper section and a beryllium lower section which is drawn into the core during operation. The rods surrounded by fuel have fuel lower sections which are drawn into the core during operation. Thus, in operation, the reactor core and reflector are composed of the solid beryllium reflector with an off center block of fuel assemblies. This picture is somewhat modified by the addition of experimental holes and regulating rods in the reflector.

12. Fuel Assembly (See Figure 4)

The MTR fuel assembly consists basically of 19 equally spaced curved fuel plates roll swaged into aluminum side plates. The fuel section assembly is 2.996 in. (from side plate to side plate) by 3.069 in. (from the bottom of the concave surface of one outer fuel plate to the top convex surface of the other outer fuel plate) by 24-5/8 in. long. The side plates and outer fuel plates extend 2 in. longer on each end for attachment to the upper and lower adapters or end boxes. The upper end box is a hollow aluminum casting with a circular cross section at the top and with the bottom shaped like the fuel section assembly cross section. The lower end box is also a hollow aluminum casting with the top shaped to adapt to the fuel section assembly, but the bottom is essentially square in cross section. End boxes (adapters) control fuel element positioning in the upper and lower assembly grids. The lower end box incorporates flat pads and beveled lands which are intended to keep the assembly vertical when the upper assembly grid is not in place and to establish the vertical elevation of the assembly in the core. The upper end box is circular in cross section and is fitted with a compression spring and collar. This end box fits into the upper assembly grid. The placement of the grid compresses the spring

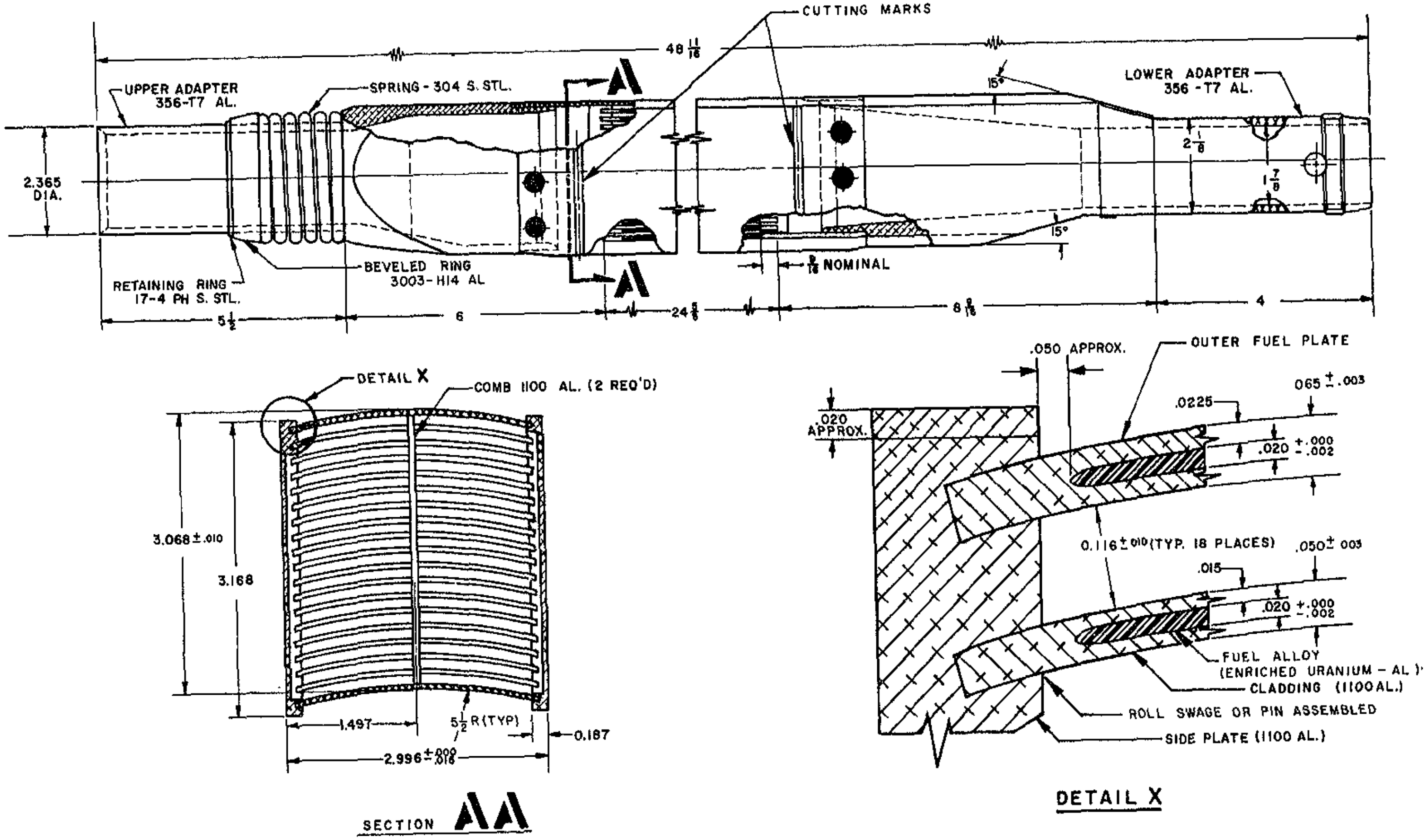


Figure 4

Materials Test Reactor Fuel Assembly

slightly, thus holding the assemblies firmly in the lower grid and eliminating vibration that may be caused by the water flow. The end boxes are designed for minimum pressure drop and uniform flow distribution between each fuel plate and between adjacent fuel assemblies.

Cooling water flows down through the inside of the upper end box, between the fuel plates, and exits from the fuel element through the lower end box. This flow through the fuel elements constitutes the bulk of the MTR process water requirements. Water also flows between fuel assemblies to cool the outside surfaces of the outer fuel plates and side plates. The balance of the cooling water is utilized to cool the reflector and reactor experiments.

The fuel plates are fabricated by cladding a core of highly enriched U-235 aluminum alloy with aluminum.

The fuel plates are roll swaged into the side plates, and the end boxes welded to the side plates and outer fuel plates. The end boxes are then machined to the finished dimension. All material used in the finished assembly is aluminum except for the stainless steel spring and retaining ring on the upper end box. The original 140 g elements had insufficient excess reactivity to keep up with the rapidly increasing experimental load. Therefore, it became necessary early in the operation of the MTR to redesign the fuel elements with a higher gram content. This has been done twice since operations started in 1952--once at 168 g, and again at 200 g. The present fuel elements contain 200 g of U-235.

13. Shim-Safety Rods

The MTR shim-safety control functions are accomplished by the use of seven shim-safety rods. Eight shim rod positions were included in the original MTR design. One of these, referred to as the L-42 facility, was converted for experimental use in the final phase of MTR construction.

The three shim-safety rods in the fourth row (fourth row from the extreme north side of the lattice in positions L-44, L-46, and L-48) are cadmium-beryllium shim rods which are used for reactor startup and shutdown only. The remaining four shim-safety rods are cadmium-uranium shim rods located in positions L-22, L-24, L-26, and L-28 in the second row of the active lattice. The Cd-U shim rods are used for reactor startup and shutdown, but they are also used as power level "coarse" controls during the reactor operation. The seven shim-safety rods can overcome an excess reactivity of about 40 percent.

The length of the unit is explained by requirements not directly associated with the functioning of the core. Since the shim rod is coupled electromagnetically to the vertical drive rod, the shim rod length requirement is affected by the radiation level that an electromagnet could tolerate. The shim rod armature is connected, through a ball and socket joint to allow for minor misalignment, to an approximately square aluminum tube about 52-1/2 in. long.

The poison section is about 31-1/2 in. long, is shaped externally similar to the fuel section assembly, and contains cadmium sheets which are used for neutron absorption. The poison section is hollow, the inside dimensions conforming to those of the upper aluminum tube.

The fuel section of the shim-safety rods is similar to that of a fuel assembly, except only 14 internal fuel plates (no outer fuel plates) are used. Thus, the shim rod fuel section is completely enclosed by an aluminum section shaped like the fuel assembly.

Attached to the bottom of the fuel section is the lower section, about four feet in length, which includes a shock absorber plunger. The over-all length of the shim rod totals 13 ft. 7-9/16 in. While the length of tubing above the poison section was needed to keep the magnet out of the high radiation flux zone, the tubing below the fuel section placed the shock absorber section just above the bottom plug with the rod fully inserted. The bottom plug was convenient support for the shock absorbers.

The shim-safety rod cooling water enters slots milled in the tubing just below the magnet armature, flows downward through the poison and fuel sections, and leaves the rod through the slots in the tubing just above the shock absorber plunger section.

The poison-beryllium shim-safety rod differs from the poison fuel rod in that a beryllium block, shaped similarly to the fuel section, replaces the fuel section. Cooling water requirements for this rod are reduced, and the flow is controlled by small longitudinal holes drilled in the beryllium block.

14. Regulating Rod

While the original design of the reactor core called for four regulating rods, two in the beryllium reflector directly adjacent to the active lattice on the north and two similarly on the south, only the two rods on the north are used. The two positions on the south are used for hydraulic rabbit or other experimental facility positions. The original MTR regulating rod has a diameter of 1-1/2 in. and is 11 ft. 7-1/2 in. long. The rod is made of aluminum tubing, and the 21-1/4 in. cadmium section is located 38-1/2 in. from the rod lower end.

Two collars are located on the rod. One, used to lift the rod when making connection to the drive rod, is removable and is located about four feet above the top of the cadmium section. The other collar is permanently welded to the rod and is used as a stop or rod support collar. This collar rests on the top of the upper support casting when the drive rod and regulating rod have been disconnected. Because the NE regulating rod lower bearing was malfunctioning, a new combination bearing assembly and sleeve was fabricated and installed. The sleeve takes up a portion of the radial space previously used by the regulating rod; therefore, a new regulating rod was built with a diameter of 1-1/4 in. The #2 rod was similarly modified in 1961.

When the top plug is to be removed from the reactor, each regulating rod is disconnected from its drive rod by means of a drawbolt which is located inside the drive rod and extends from top to bottom of that rod.

15. Beryllium Reflector

The beryllium pieces occupying positions in the active lattice not occupied by fuel assemblies and shim-safety rods are termed "L" pieces and have an external shape similar to a fuel assembly. Since the function of the "L" piece is to extend the reflector to the south boundary of the fuel assembly group, the center portion of these pieces consists of a beryllium block. End boxes similar to those used on fuel assemblies are riveted to this block. The beryllium block is pierced by a number of longitudinal holes for the flow of cooling water.

The beryllium reflector surrounding the active lattice is assembled from a large number of individual pieces. The majority of these pieces rest on spacers on the lower support casting. Only the "A" pieces are fitted with circular lower end boxes to fit into mating holes in that casting.

The key reflector pieces are the four containing the vertical holes used by the two regulating rods on the north and two hydraulic rabbit facilities on the south. These pieces are numbered E-1 through E-4. Large pieces are machined to fit around the HB thimbles projecting inside "D" tank. These are "N" and "F" series pieces. Forty-three "A" pieces fill a large portion of the remainder of the reflector volume and are about 3 in. sq. in cross section. Other wedge-shaped pieces, "B", "C", "J", "K", and other series, are used to complete the cylindrical shape and outline the active lattice. One unit, previously mentioned, is the "D" piece which covers the discharge chute placed below the reflector on the east side of the core.

The close tolerance machining of the reflector pieces allows operation of the reactor without restraining the reflector pieces by clamps, end boxes, etc. Where required, external or internal cooling of the individual pieces is accomplished by means of small diameter holes between outer surfaces or drilled longitudinally throughout individual pieces.

The reflector pieces that may be removed from the top are fitted with lifting pins which match special handling tools designed for that purpose. Those pieces moved with the greatest frequency are the "A", "B", and "D" pieces. The "L" pieces in the active lattice are handled with tools used for the fuel assemblies.

16. Shim-Safety Rod Drive

Since the shim-safety rods in the MTR are made with a poison upper section and a lower fuel section and were designed for vertical travel, a drive was designed to move these rods at a controlled (approximately 5 in. per min.) rate of speed. The drive rods are magnetically coupled to the top of the shim-safety rods during reactor operation. In the case where the reactor must be shut down quickly, the current to the electromagnet is cut off allowing the shim-safety rods to fall into the core. Only the drive rod and electromagnet operate inside of the reactor vessel. All other components are located above the reactor top plug on the drive platform.

The 1-1/2 in. diameter drive rod extending through the reactor top plug is connected at its upper end to an externally threaded rod. This threaded rod is moved vertically by a rotating worm gear which is held in a fixed vertical position in a cast iron housing and is internally threaded to match the drive rod. The worm gear is, in turn, rotated by an electric motor-driven worm. The threaded rod thus moves only in a vertical direction carrying with it the electromagnet and the shim-safety rod.

Other features of the drive mechanism include limit switches which are actuated by a projection on the top of the threaded rod and are mounted in a housing. The entire drive rod is hollow and carries a multiconductor cable to transmit current to the electromagnet. These wires terminate at a fixed terminal mounted on top of the drive rod. Since the top of the drive rod moves up and down inside of a fixed housing, coiled cords, similar to those used on telephones, are used to carry the electrical connections from the terminal lug to the outside of the drive housing. This cable emerges at the top of the drive housing and is connected to junction boxes mounted on the top plug platform.

Two methods are used to indicate shim-safety rod position in the core. A direct mechanical connection is accomplished by means of a flexible shaft which is geared to the drive motor and is connected to a decade counter. This counter is similar to those used to indicate mileage on an automobile speedometer and is mounted on the top plug platform. Another method was necessary to indicate to the console operator the rod position. An electric selsyn geared to the drive motor drives a slave selsyn dial and pointer combination which is mounted on the control console. This indicator is only a rough indication of level and actual leveling of the rods is accomplished by use of the speedometers at the top plug.

A packing gland seals the drive rod housing to eliminate contamination of the process water by the lubricating oil in the threaded worm gear housing. The gland is mounted just above the top surface on the top plug, leaving the drive rod exposed below that point. The drive rod in turn passes through a seal in the reactor top plug. Slight leakage of contaminated process water through this seal is eliminated by the addition of an auxiliary upper seal and the introduction of pure demineralized water into the zone between the two seals. This water is a pressure slightly greater than that of the reactor vessel; so any water leakage out of the upper seal is drained by suitable piping.

The original electromagnet used in reactor operation was a conventional bipolar type designed to lift a 500 lb. load with 100 ma current and to drop a 600 lb. load held with 140 ma current in 15 milliseconds or less. In 1957, the magnet was redesigned

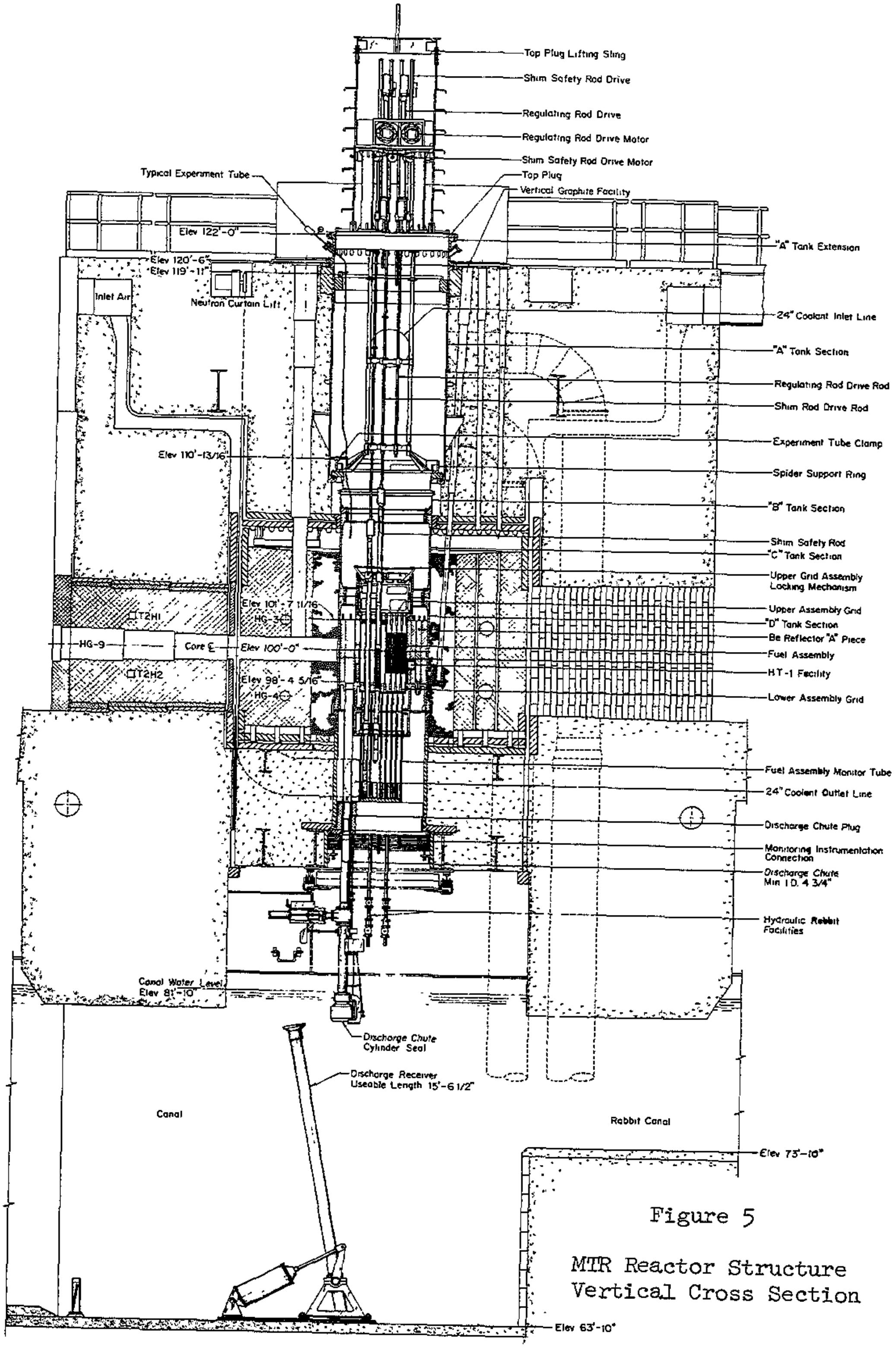


Figure 5

MTR Reactor Structure
Vertical Cross Section

utilizing a cylindrical shape. The housing body is made of magnet quality iron as is the central core piece. Filling the annular space is the wire coil. This housing is sealed by a threaded top cap and a single O-ring. This magnet design has been very successful in greatly reducing reactor down time due to magnet maintenance. The magnet housing is insulated from the drive rod and forms a part of an electrical circuit used to indicate contact with the shim-safety rod.

While the shim-safety rod is used to control the reactor power level on a "coarse" scale, a regulating rod is used to provide rapid "fine" control. The drive mechanism for the regulating rods must move a much smaller combined weight of rod and drive rod than that of a shim-safety rod, but at a much higher rate of speed.

17. Regulating Rod Drive

The regulating rod is connected to its drive rod by a draw-bolt that passes through the drive mechanism and the drive rod. The end of this bolt screws into a 1/2-in. female thread on the top of the regulating rod. The drive rod passes vertically upward through a reactor top plug seal similar to those used on the shim-safety drive rods.

The drive rod makes connection on its top end with a rack which is driven by a gear. The gear is connected to turn, through a single reduction gear, to a one horse-power direct current motor. This motor is controlled automatically by the reactor control circuits.

Like the shim-safety rod drives, a regulating rod position indicator is included at the console. A selsyn, geared to the rod drive, transmits to a selsyn mounted on the control console. This is connected to a dial-pointer type position indicator similar to the shim-safety rod indicators.

18. Reactor Instruments

a. Introduction

Fossil fuel fired furnaces rely on instrumentation to reveal what is going on inside. Instruments are provided for stack gas analysis, stack gas pressures, fuel oil temperature and pressure, structure temperature, etc. Nuclear reactors, with no means for visual observation, must rely even more on instruments to indicate what is taking place within them. Being totally different from other furnaces, nuclear reactors must use a greater variety of instrument applications to convey internal information to the operators. In the MTR there are three groups of instruments furnishing information to the operator and the control system: (1) the reactor instruments measuring neutron flux or power level, (2) the rod position and motion indicators, and (3) the instruments for the auxiliary facilities. Reactor instruments will be understood to include radiation instruments measuring gamma and neutron levels in the reactor and radioactivity in the water, temperature instruments measuring distribution of exit water temperature across the active lattice and temperatures in the thermal and biological shields, and pitot tubes measuring distribution of water flow across the bottom of the active lattice.

b. Reactor Control Instrumentation, Rods, and Drives

The MTR control rods are of two types, the shim-safety rods for coarse neutron level control and the regulating rods for fine control. Both types of control rods lower the reactivity of the reactor when they are inserted; and when all are resting in their lowest possible position, they overcome an excess reactivity of more than 40 percent. Since normal fresh loads contain 13 to 15 percent excess, this provides an adequate margin of safety. For purposes of reactor operation, suffice it to say that reactivity is overcome by means of neutron absorption. This is accomplished by cadmium built into the control rods. Cadmium has the high capture cross section of 27,000 barns.

(1) Shim Rod System

The shim rod system is the means provided for the operator to control the reactor. With this system it is brought to criticality, manual control is exercised, and shutdowns are initiated. Pulling the shim rods upward (withdrawal) gives an increase in reactivity. Conversely, the reactor may be shut down by running the shim rods in (insertion) or by shutting off current to the electromagnets and allowing the rods to drop ("scram") by the force of gravity and water flow. When the rods rest in their lowest position, the cadmium is in the lattice, and as the rods are withdrawn, the cadmium in the lattice is replaced by fuel or beryllium, as the case may be.

The shim rods are connected to their drive mechanisms by electromagnets (clutches). Two magnet amplifiers in parallel supply the current for each magnet; and if one amplifier fails, the other automatically takes over the full load. Two ways of stopping magnet current to produce a scram are provided. The first of these, called a <u>fast scram</u> because of its fast response time, is electronic in action. The output current of the magnet amplifiers is controlled by the highest signal from the sigma amplifiers. If the reactor neutron level reaches 1.5 N_F, the sigma amplifiers affected will raise the voltage of the sigma bus, reducing magnet current by amplifier action, and thus cause one or more shim rods to drop. All this can take place in less than 30 milliseconds.

The second method of producing a scram is through mechanical relays. Either of the two "SCRAM" switches on the console may be thrown or any of the scram contacts in the recorders or experiments may be tripped. All these activate the same relays producing the mechanical (<u>slow) scram</u>. All rods drop, as current is interrupted to all magnets, within 100 milliseconds after the initiating scram signal.

For a clear understanding of the operation of the shim rods, it is imperative that the reader distinguish between the shim-safety control rod and the shim-safety rod drive assembly. The shim rod drive mechanisms are an integral part of the top plug and are driven by 1/6 hp, reversible, three-phase, induction motors with worm gears. The advantage of the induction motor is that no accident can make it run in excess of synchronous speed; therefore, the danger of overspeed withdrawal of the shim-safety rods is eliminated. No brake is required since the worm and screw drive is self-locking.

The shim rod motors are remotely controlled from the console by a variety and combination of switches.

(2) Servo System

The servo mechanism is the automatic reactor control for the power range N_L to N_F. The operator selects the desired power level by means of the Motor Operated Rheostat (MOR); and if the flux level of the reactor as seen by the servo ionization chamber is different from the MOR setpoint, the system will adjust to the correct flux by moving the regulating rod in or out of the core. Since the regulating rod reactivity is small, the operator must move the shim rod periodically to keep within range of the servo system.

The regulating rods are designed to provide continuous fine control of the reactor neutron level. Four possible locations for regulating rods are provided in the beryllium reflector adjacent to the active lattice. Normally, only one regulating rod is used for control of the reactor with one rod available as a standby. The remaining two locations are used as experimental facilities.

The following reactor radiation instruments are used for measuring the neutron flux or power level. For detailed descriptions of these instruments, refer to the Reactor Instrument section of "Fundamentals in the Operation of Nuclear Test Reactors".

REACTOR RADIATION INSTRUMENTS

Instrument	Use
Fission chamber (12 ft. travel)	Count rate meter
Compensated ion chambers	2 log N's and period signals, galvanometer signal
Parallel circular plate ion chambers	3 neutron safeties and 2 servo systems
Boron thermopiles	Neutron flux in graphite
Air wall ion chambers	N^{16} in cooling water
Water ion chamber	Water sample monitor

(3) Iodine Monitor

If a fuel element should rupture, the fission products released to the process water would contain several isotopes of iodine. These can be collected in an anion absorbing resin and counted. Since a rise in iodine gamma activity is indicative of a uranium fission product leak, the system is important in discovering fission breaks.

The filters in this system must be changed weekly. Health Physics must monitor this change, then mount the filter on a cardboard mounting card, and deliver it to the Counting Room.

19. Sub-Pile Room

The bottom of the reactor bottom plug is accessible from the sub-pile room. This room is divided by the canal passing through its center in an east-west direction. The floor of the sub-pile room is at the same elevation as the basement floor, and access to this room is through two heavy shielding doors. One door is located on the north side; the other is on the south. Gratings over the canal parapet in the sub-pile room allow personnel to reach either side of the room for maintenance work. During the first few years of reactor operation, personnel could enter the sub-pile room during periods when the reactor was at power. In later years radiation emanating from the experiments which penetrate the sub-pile room has prohibited access except during shutdowns.

During shutdown it is usually necessary to enter the sub-pile room to inspect or repair the unloader mechanism or to do maintenance work on the hydraulic rabbit facilities or on one of the inpile experimental lines.

Any maintenance work requires a safe work permit; and since this area is highly contaminated with wet spots on the floor, parapet, and metal grid from either process water or water from the primary systems of the inpile experiments, Anti-C coveralls, a head cover, latex boots, and rubber boots are required.

If a primary water line or inpile experiment line is being opened, respiratory equipment with a full face mask should be used. Prior to entry, a constant air monitor sniffer hose should test the activity, and during the work, the hose should be placed near the working area to warn of any gaseous releases when lines are broken.

Due to the potential radiation hazards in the sub-pile room, rigid precautions are required to assure personnel safety. Health Physics' responsibility is to recommend the protective systems and the precautionary measures to be followed when it is necessary to enter and work in this area.

a. Protective Systems

(1) The outer sub-pile room doors are equipped with a dual lock system. One lock requires a standard area key which must be obtained from the duty Shift Supervisor. This provides supervisory control of any sub-pile room entry. The second lock requires the Discharge Mechanism-sub-pile room interlock key. This prevents inadvertent discharge mechanism operation while the sub-pile room is open.

(2) Visual alarms (flashing red lights) located on the reactor top, at the rabbit canal, and at the discharge mechanism control panel indicate that the sub-pile room shielding doors are open.

(3) Audio and visual alarms are also installed to indicate the discharge mechanism receiver positions. If the receiver is not in the horizontal position, the following alarms will actuate.

(a) A continuous bell in the sub-pile room provides the audio signal.

(b) Flashing red lights located above the sub-pile room doors provide the visual warning.

In the event either of these systems actuates, the sub-pile room and immediate vicinity should be evacuated until the alarm is cleared and a Health Physics survey indicates that the area is safe for re-entry.

b. Restrictions

Adequate radiation monitoring instrumentation must be available and in use whenever the sub-pile room shielding doors are opened. Except in extreme emergency, as directed by the Shift Supervisor, a health physicist must be present. The HP will provide a pre-entry survey and continuous monitoring while the sub-pile room is open.

After the initial entry the HP should check the remote monitoring head to be certain it is functioning properly. A check should be made with the HP office to have the alarm point set close to the actual reading and also to be certain the alarms (visual and audio) in the sub-pile room and the HP office are working. Then, during prolonged periods of maintenance work, any change in the radiation level will immediately be detected.

c. Rules to Follow

When it is necessary to proceed with reactor in-tank work while personnel are in the sub-pile room, the following minimum requirements must be satisfied:

(1) The lead discharge chute plug and "D" piece (or dummy) must be in place.

(2) Normal water levels must be established in those inpile tubes (such as KAPL-L-42 and WAPD-VH-3) that penetrate the bottom head, and tube closures must be in place.

(3) The hydraulic rabbit tubes must be empty (no samples) and the facilities locked.

(4) When special jobs are performed that require concurrent effort by personnel on the reactor top and in the sub-pile room (such as KAPL-L-42 inpile tube changeout, or monitor tube replacement), other in-tank jobs will be suspended. During this time, the provisions of (2) above will apply.

Due to the fact that an electrical power failure can result in hydraulic rabbits passing through the sub-pile room, the following procedures regarding entry into the sub-pile room will be followed during periods of reactor operation.

(a) No entry into the sub-pile room may be made while the hydraulic rabbit facilities (VH-1, 2, 4) are in use.

(b) If entry into the sub-pile room is required for maintenance or inspection while the hydraulic facilities are in operation, all rabbits and spacers must be removed and counted prior to such entry. Prior approval of the Shift Supervisor will be required for this procedure.

20. Canal

The use of water as a shielding medium allows direct visual contact with radioactive components and also allows the use of simple tools in the handling of these pieces. It is for this reason that the canal located in the reactor building basement is considered an integral part of the over-all facility design.

The canal contains the equipment for the handling of assemblies discharged from the reactor and provides space for the storage of spent fuel assemblies, irradiated materials, and internal parts of the reactor. Water over these materials protects the operating personnel from the hazards of radiation.

The main section of the canal is 8 ft. wide and extends eastward from the east face of the reactor. The canal section termed "rabbit canal", that lies partially beneath the reactor west wall, is 6 ft. wide. A 7 ft. wide canal connects these sections and extends through the reactor sub-pile room. The width of this section provides ample space for the canal unloading mechanism.

The parapet around the canal is 10 in. thick at the bottom and projects outward at the top to a width of 13 inches. This projection provides toe space and also gives the operator better stability when working over the parapet. The top of the parapet is 3 ft. above floor level.

The bottom of the hydraulic rabbit canal is 6 ft. below the basement floor level and that of the main canal is 16 ft. below the basement floor level. The water level in the canal is maintained 2 ft. above the basement floor level, providing depths of water in the rabbit canal and main canal of 8 ft. and 18 ft. respectively.

The depth of water in the canal is sufficient to shield adequately against the fission product gammas from the stored reactor fuel assemblies. The main canal water depth of 18 ft. limits the radiation levels to 0.1 roentgen per 8 hr. at the water surface over the fuel storage area.

Outside of the reactor building, the canal has a 6 ft. working space on each side and at the east end. This working space is enclosed by a tunnel or canal envelope 13 ft. 8 in. high and 21 ft. wide. The tunnel extends 87 ft. 6 in. beyond the reactor building east wall.

The canal walls were originally covered with 8 by 16 in. white glazed structural tile 4 in. thick, and the bottom was lined with

4 in. of white concrete. Excessive leakage made it necessary to install a stainless steel liner.

A flow of 20 gpm of demineralized water is maintained through the canal to avoid an excessive build-up of radioactivity and turbidity. As originally installed, water from the canal overflowed a weir in the east end of the canal and flowed through a discharge pipe to the canal sump. An overflow pipe was installed west of the old RMF canal isolation gate, and use of the overflow weir was discontinued.

Provisions are included for the installation of two removable watertight bulkheads which permit isolation of any canal section, except the rabbit canal, for cleaning and maintenance. Each section, except the rabbit canal, is also provided with a drain and a water line connection. The drains are interconnected in such a way that any section can be isolated and flushed. There are three adjustable over-flow standpipes in the sub-pile room and rabbit canal section. A continuous over-flow to the reactor building sump is maintained through these in order to prevent scum formation.

Good underwater lighting is necessary because the handling of assemblies in the canal is a manual operation carried on under 10 to 18 ft. of water. This lighting is supplied primarily by portable watertight light fixtures.

A manually-operated bridge crane with a 2 ton electric hoist and manually-operated trolley is provided for the handling of heavy materials in the main canal. The highest hook position is 9 ft. 9 in. above the reactor building basement floor. This provides a clearance of more than 6 ft. between the hook and the top of the parapet. The maximum lift of the hoist is 25 ft. 9 in.

Besides Operations work on the reactor top during shutdown there is considerable work at the canal; this requires the constant monitoring of an HP. The HP should also be sure the monitoring instruments relied upon are working properly. During the decapsuling of experiments, he should be alert for bubbles releasing radioactive gases or for light materials which could float and cause high radiation fields. The working table used to identify capsules should be deep enough under water to prevent excessive exposure to working personnel. The spread of contamination is a constant hazard during canal work, and the HP should recognize conditions which can possibly cause this and take steps to prevent it. The HP taking over a job around the canal should be made aware of any hazardous conditions which exist.

a. Canal Procedure

All objects raised to the surface of the canal or the rabbit canal should be monitored as they are being raised. This will prevent personnel from receiving overexposures when mistakes are made in the estimated activity of objects being raised to the canal surface.

Personnel working in the canal areas should be cautioned to prevent objects with very high activity from approaching the surface of the canal. An example which illustrates how a serious personnel exposure could have been received follows.

Men unloading spent fuel from the reactor were hanging fuel elements, fastened to a handling tool, from the canal bridge and were pushing the bridge down the canal to the fuel racks. The bridge was being pushed down the canal so fast that the fuel element came up far enough in the water to set off the alarm on the Beckman canal monitor. A very serious exposure could have been obtained by these men if the fuel element had risen a few more inches toward the canal surface.

The maximum radiation exposure level which will be tolerated in dry loading of samples from the canal is, generally, 1 rem/hr at 5 ft. in air and up to 10 rem/hr at 5 ft. in air with specific authorization of the Superintendent in charge of Operations.

The HP should always be sure that the workman who is raising the object being monitored from the canal is aware that he should quickly lower the object back into the canal water whenever the HP monitor orders him to "take it down".

As the object is being raised through water toward the top of the canal, the survey instrument (preferably a cutie pie or juno) should be held over the canal at a distance of approximately 4 ft. from the spot where the object will break the surface of the water. The object should be raised until the radiation level approaches 1 rem/hr. If the remaining water shielding is over 6 in. it will be useless to try to bring the sample out into the air.

Just before the radioactive sample breaks the surface of the water, the monitoring instrument should be moved back to 5 ft. from the point where it will break the surface; the radiation level being recorded by the instrument should be watched very closely. The instant there is any indication that the radiation level at 5 ft. from the object, in air, will be greater than 1 rem/hr, the operator should be order to "take it down".

Any questions as to the advisability of bringing the object out into air if it reads more than 1 rem/hr at 5 ft. should be referred to the Superintendent of MTR Operations.

In order to insure that a critical array of fuel will not be inadvertently assembled in the reactor canal, the following practices must be strictly observed.

(1) If space is available, always store fuel elements in approved storage racks or grids. These storage grids are lined with at least 20 mils of cadmium sheet.

(2) If all storage grids are full, fuel may be temporarily stored in the gamma grid.

(3) In the event all storage and gamma grids are full, line the elements along the canal wall in a single row end to end.

(4) Under no circumstances is a fuel element to be stored in a working grid.

(5) Never store Be pieces with fuel elements.

Although the responsibility of handling these fuel pieces lies with Operations, the HPs should be aware of a possible criticality; and if any deviation from this procedure is observed, they should take the necessary steps to see that the situation is corrected.

b. Canal Trash

All fuel and boxes, bent X-baskets, capsule containers, and other useless articles from the canal are placed in metal trash cans and are shipped to the burial ground for disposal. Because of the high radiation levels from these pieces, extreme care should be used in this shipment. The trash cans are placed in a lead cask in the canal by the overhead crane and then loaded on the low boy truck. If the radiation fields 1 meter from the edge of the truck exceed 500 mr/hr, an HP escort must accompany the shipment to the burial ground.

c. Discharge Mechanism

A device which remotely connects to the discharge tube located on the reactor vessel bottom plug and transports components from the reactor vessel to the canal is called the "canal discharge mechanism". This mechanism consists of a long cylinder pivoted at its lower end and contains a piston which is moved by water pressure. The cylinder has a sealing device at its upper end which mates with the lower end of the fixed discharge tube. Radioactive components are lowered from the reactor core into the discharge chute, past a full-opening valve, and into the discharge mechanism cylinder where they rest on the movable piston. The valve is closed; the mechanism breaks connection with the discharge chute, and the cylinder then pivots to the east, coming to rest in a horizontal position. The piston then is moved to eject the component onto roller platforms where it may be handled or moved by handling tools.

d. Underwater Saw

Since the life of a fuel assembly or shim-safety rod in the reactor core is not long enough to burn more than 25 percent of its total uranium content, the unused uranium is reclaimed by a chemical dissolving and separation process. As the end boxes in the case of the fuel assemblies or the poison section, etc., in the case of the shim-safety rods contain no fuel, they are removed before the fuel sections are transported to the chemical processing plant. They are removed by a hack-saw operating under water in the canal.

e. The Snake Pit

Access to the snake pit is through a hatch south of the canal near the east reactor wall. This access leads to the process water inlet and outlet lines where two thermocouples are placed. Instrument maintenance must repair these instruments occasionally.

Access to the pipe tunnel is also gained through this hatch. This area is damp and highly contaminated from water spills from the primary system. Because the canal is overhead, an HP should make certain all fuel elements are removed from this canal section before entry is made. High radiation is also possible from floating sources in the primary system. A CAM sniffer should be used to check the air in the pit before entry is made.

f. Canal Sump Pit

The canal sump hatch is located south of the canal and east of the hatch to the snake pit. As the water level in the sump rises, two 100 gpm pumps driven by 5 horsepower-1750 rpm motors automatically transfer the canal water to the Retention Basin inlet.

The sump pit is highly contaminated and has damp surfaces. High radiation readings can be found at the base of the pumps. Entry into this pit is usually for pump inspection or repair. A CAM sniffer hose should be lowered into the pit before entry. Anti-C clothing, head cover, latex boots, and rubber gloves should be worn.

21. Plug Storage Facility and Cask Procedures

The MTR plug storage facility provides a low-cost shielded facility for the dry storage of radioactive beam hole plugs. These plugs may be the dummy plugs which were original equipment installed in the reactor, or plugs incorporating a specific experiment.

In 1957, a new enclosed facility was constructed on the reactor building north side. The new plug storage facility is connected to the reactor building by an existing truck door and to the plant by a new roll-type truck door.

The plugs are ejected from the universal coffin into pipes or rectangular tubes at elevations approximating those of the beam holes in the reactor structure. The tubes extend 29 ft. beyond a concrete facing wall. The tubes are embedded in gravel to obtain the necessary shielding, and the gravel is retained by concrete wall on the other three sides. The top of the gravel is exposed to the weather; any water entering the top of the fill is drained by perforated drain piping.

Twenty-one tubes are made of 10 in. schedule 50 carbon steel pipe. These may contain the beam hole plugs which are circular in cross section. In addition, one tube about 15 by 21 in. is used for the HG-9 plug storage and another about 15 in. sq. is used for the VG-9, T2V1, or T2V2 plugs. Two tubes, 5 in sq., may be used for storage of the HT-1 plugs. The tubes are capped by welded plates on the ends embedded in the gravel and by gasketed and bolted plates on the exposed or charging ends.

After monitoring for the transfer of a dummy plug or an experimental plug to this storage facility, the HP should carefully check the area for contamination and also determine that no high radiation beams are coming from the hole. Shielding should be placed in the hole to lower any fields around it to permissible levels. This is also an area which should receive careful attention during the hazardous area check.

22. Cask Procedure

All casks used for shipping fuel, capsules, or other pieces from the canal are lowered by the overhead crane through an open hatch in the first floor to the canal. A structural steel pad distributes the load to the piers supporting the canal floor.

An HP must be present any time a cask is brought out of the canal. All casks which are brought out of the canal must be smeared and should not be moved until contamination levels are satisfactory.

a. MTR Carrier (See Figure 6)

This carrier is used to shield the cut fuel assembly and shim-safety rod fuel sections when they are transported from the MTR canal to the MTR gamma building or the Chemical Processing Plant (CPP). It is fabricated of stainless steel and is lead filled. About 14 in. of lead surround the center cavity on the sides and top, and about 17 in. is used on the bottom. This carrier weighs approximately 25,300 pounds.

The carrier can hold four cut fuel sections. It is loaded underwater in the canal, a plug is inserted in its top, and it is lifted to the main floor using the reactor building 30-ton crane. The straddle carrier picks up the carrier and transports it to its destination.

When the fuel carrier is loaded there is a danger of boiling the water if there is a time delay in moving it out. If this carrier is out of the canal longer than 35 minutes, water must be added to the cask. When several shipments are made with fuel elements having little cooling time out of the reactor, the cask must be cooled between loads. This is accomplished by letting the cask, without top, stand in the reactor canal for approximately 1 1/2 hours.

b. Universal Coffin

The removal of the various beam hole facility plugs, either startup or experimental, and their transport to a plug storage facility requires the use of a shielded coffin. The coffin used for this purpose consists basically of a steel pipe which is jacketed with about 10 in. of lead and is large enough to contain the largest beam hole plug. Removable inner liners are provided to adapt the coffin for use with smaller plugs. The lead jacketing is thickest in the area surrounding the plug tip which should be the most radioactive section of the plug. This coffin is moved

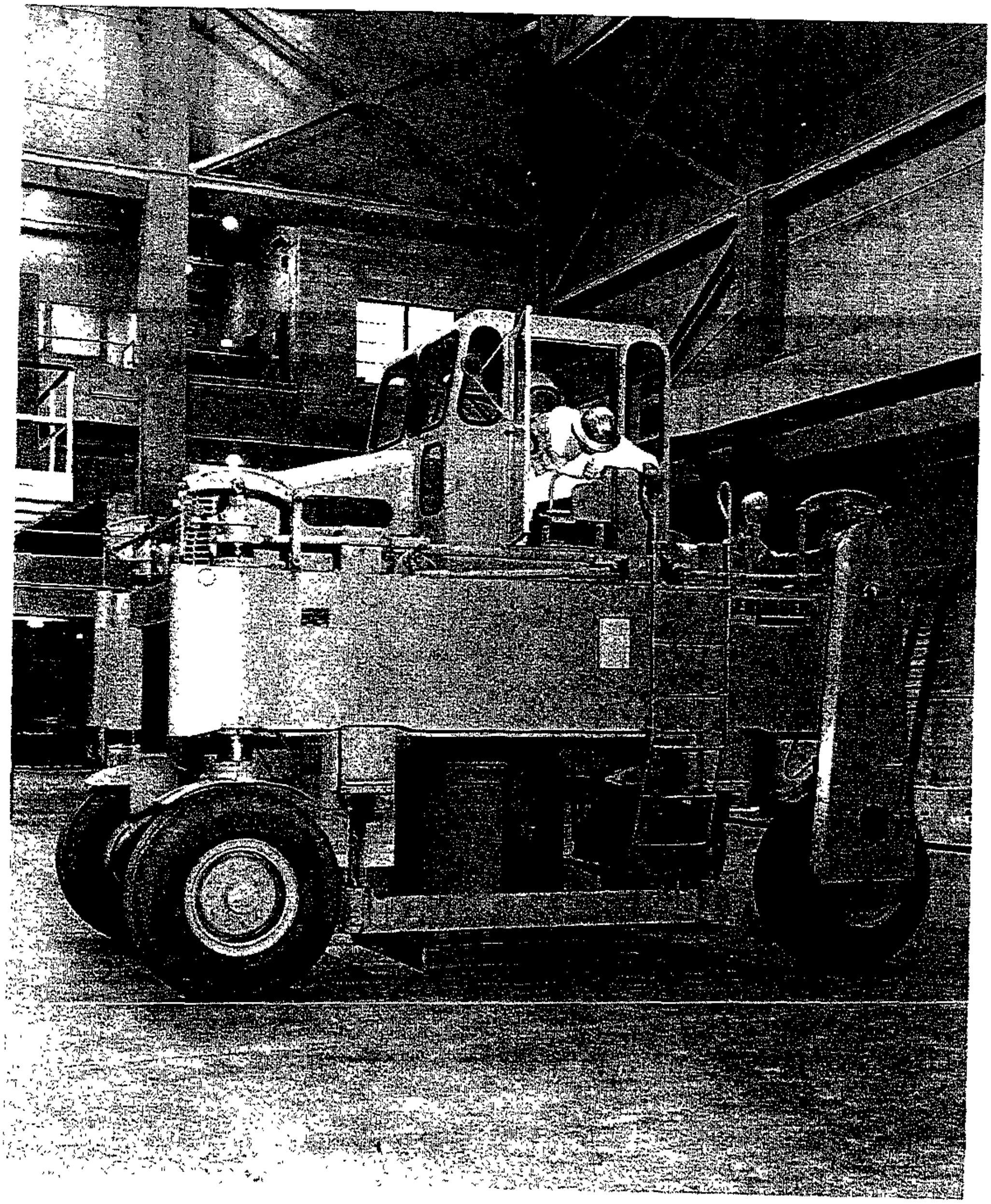


Figure 6

CPP Straddle Carrier Picking Up MTR Fuel Element Cask horizontally on a dolly and is leveled and adjusted to match the centerlines of a beam hole facility. Horizontal and vertical beam hole centerlines have been painted on the reactor structure and the reactor building first floor to aid in aligning the coffin. The coffin is fitted with a heavy radiation door to close off the end near the plug tip. It must be rotated 180 degrees to match some beam holes. The basic coffin consists of three sections. The tip section is heavily shielded and has a motor-operated radiation door mounted at its outboard end. The second section is heavily shielded at its point of attachment to the first section but tapers to provide approximately 4 in. of lead shielding equivalent at the other end. The third section consists of a length of 10 in. pipe with flanges on both ends. These three sections are approximately 17-1/2 ft. long and weigh approximately 32,000 pounds. One additional section is also provided for use with the HT-1 plug which has an extra long radioactive section. This front section bolts on the face of the tip section, is 5 ft. 3 in. long, and weighs 9000 pounds.

B. MTR Cycle

1. An Overview

A reactor cycle has been set for a three week period consisting of about 3 1/2 days of shutdown and the balance of the time devoted to operating the reactor at 40 MW. This is a fixed cycle to allow experimenters to plan their experiments in advance.

Operations strives to operate the reactor as continuously as possible with the shortest periods of down-time possible. However, the prime purpose for operating this installation is to provide experimenters with the best service possible with a reasonable margin of safety to operating personnel.

A cycle begins with a reactor shutdown. The shutdown period is a time of radiation and contamination hazards. The top plug is removed, the reactor is refueled, experiments are changed out, and capsules are removed from many of the facilities. Any change in experimental loops or in-tank piping is done at this time. Any maintenance work completed during shutdown on a loop experiment requires a written procedure prepared in advance to prevent damage to the experiment or unforeseen hazards to the personnel. A work schedule is given to the Health Physics foreman prior to the shutdown, and during the shutdown the jobs are discussed at a daily shutdown meeting with Maintenance and Operations supervision. A work order is written for each maintenance job to be accomplished; and a Safe Work Permit, if a potential hazard exists, must accompany each work order. Prior to the commencement of work, all Work Requests and Safe Work Permits must be carefully considered and signed by the shift supervisor. Constant Health Physics monitoring is required on the reactor top while men are on the top with the top plug removed.

When shutdown work is completed the upper grid is brought from the canal and lowered into position with the 5-ton crane. Then the top plug is placed in position and bolted securely. All necessary connections are made, and a check is made by Operations on all experiments and routine reactor procedures. When everything is in order for the reactor startup, approval will be given by the Shift Supervisor; and he will order the console operator to start up. The reactor is taken to power slowly under the direction of the senior reactor engineer. Power is raised in 5 MW steps to 30 MW and 2-1/2 MW steps from 30 MW to 40 MW. Checks are made by Operations personnel on the reactor, the experiments, and radiation fields as power increases. Health physics technicians make checks on all experiments during this power increase to insure that shielding around the experiments is adequate and no dangerous fields or beams of radiation are present and there are no gaseous leaks from experiments.

2. Fission Breaks

In any operating reactor, the possibility of a fission break is always present. It can be the result of mishandling fuel bearing pieces or damaging the thin cladding over the fuel. Overheating (hot spots) can also end in a fission break by melting or causing a rupture of the cladding. Improper metal-to-metal bonding of fuel bearing pieces, at the time of manufacture, will sometimes result in fission breaks.

Because of an inherent likelihood of fission breaks, the MTR has built into it a routine monitoring system that is ready to detect most fission breaks. Regularly scheduled water samples are taken to the health physicist for counting. Normal cooling water activity is around 20 to 40 thousand counts per minute per milliliter as measured in the MTR Deepwell Counter after two hours of decay. This will be about 2 to 4 mr/hr per milliliter. The reactor is shutdown when the activity of the water reaches approximately 100 thousand counts (approximately 10 mr/hr) per milliliter.

As cooling water activity rises, the "VENT SEAL" annunciator in the process water building will sound. This informs the operator that radioactive gases are being released at the evaporators. The control room "STACK ACTIVITY" annunciator will probably sound next and alert the console operator that radioactive gases are being discharged from the stack. A "FUEL ELEMENT ACTIVITY" annunciator will sound and an activity recorder will indicate which fuel element has the break, if a fuel element is involved; otherwise, all points on the recorder will rise with the activity of the water system. The "FISSION BREAK" annunciator in the control room will sound as the process water activity increases in the seal tank. Finally, the iodine monitor will show an increase confirming fission product release into the cooling water.

There are two N-16 monitoring instruments in the control room which measure the amount of N-16 present in the exit water lines. On several occasions of severe lead or capsule ruptures these instruments have been the first to detect a fission break.

At the direction of supervision, the reactor will be shut down, flushed, and the offending piece discharged.

During a fission break, lines on the face of the reactor and process water lines exposed are possible high radiation sources.

Because defective experimental fuel plates and capsules are occasionally deliberately placed in the reactor to be tested, a potentially hazardous condition exists during each cycle. Although safety circuits are built into the reactor to "scram" the reactor when capsules or fuel elements are ruptured, often a large release of activity is made instantaneously, resulting in high level air activity or high radiation fields which cannot be avoided. Therefore, it is necessary for personnel to be trained to evacuate immediately when health physics instruments alarm and leave further investigation to Health Physics. Complete evacuation of the Reactor Building is normally the decision of the shift supervisor unless he cannot be contacted; and then if conditions warrant it, the evacuation switch can be pushed by the chief health physicist on duty.

3. MTR Shutdown Procedures

There are procedures and hazards involved in a regular reactor shutdown for refueling and experimental reloading. The shutdown at 0030 on a Monday morning is usually accomplished by a reverse or setback and a scram via the relays, thus checking out one of the reactor safety circuits.

Prior to shutdown, a 1 gal. bottle of Process Water is obtained for chemical analysis, a check-out is made on all tank tools and unloading equipment, and final information on experiments is taken. An inventory of all contaminated liquid storage tanks is also made.

Removal and insertion of fuel elements and experiments in the reactor core requires the use of long tools which are intermittently inserted into and withdrawn from the reactor. The tools are wiped with clean rags when one of them has been used and withdrawn from the tank. Since it would take too much time for the reactor technicians to dry each one completely as it is removed, it is expected that drops of radioactive water will be spilled onto the working platform and spread away from it. For this reason, the reactor top is routinely prepared for shutdown work by having Health Physics isolate the necessary work area. Operations personnel cover it with blotting paper in the hope that there will not be much difficulty in cleaning the area when the in-tank work is done. The use of Anti-C clothing and sometimes respiratory protection is required in this area.

a. Removal of the Top Plug

After the HP has determined that no gases are being released into the building during the removal of the manhole cover, Operations proceeds to remove the top plug. This is accomplished by the 30-ton overhead crane. An HP must be present to monitor as the top plug is raised from the tank and taken into dry dock. He should also make a check to see that the shim rods have been released. Demineralized water is used to wash down the drive rods and magnets as they are pulled from the tank, and a drop pan is installed to prevent dripping as the top plug is moved to dry dock. The exposed areas of the tank are also thoroughly hosed down at this time to lower radiation levels. Health Physics technicians are to provide constant monitoring for work performed on the reactor top any time the top cover is not in normal operating position.

b. Working Platform

A working platform is placed over the tank for convenience and safety of working personnel. It has 1/4 in. of lead beneath the working deck to reduce the working radiation fields. A CAM sniffer should be placed above the tank inside the working platform to detect any gaseous releases during shutdown work. Care should be taken to secure the hose so it cannot fall into the reactor water. Two Tracerlab heads are placed on the working platform on instrument racks built for them. It is important that the recorder on the CAMs be timed accurately in case of an incident when the correct time must be checked.

It should be kept in mind that anything which has been in the reactor an unknown length of time is potentially very radioactive. With the exception of tools, nothing should be removed without being monitored by a health physicist.

c. Upper Grid Removal

Operations then makes preparations for the removal of the Upper Grid to the canal. This is one of the most hazardous jobs accomplished during shutdown because of the high radiation fields encountered. This transfer requires that all personnel except those actually involved in the transfer must be moved from the area, so the HP monitoring the reactor should have at least one HP stationed on the main floor and be sure the HP at the canal is aware that this operation is about to begin. If necessary the operations should be held up until the HPs are at their stations before starting this transfer. While the upper grid is being raised in the tank a visual inspection is made to be certain no capsules or fuel pieces are hanging from it. Operations will also be checking for this. The small crane (one ton) is used to raise the grid above the shim rods, and then it is transferred to the 5 ton crane which completes the transfer to the canal. Announcement of the upper grid transfer will be made by Operations over the Reactor Building intercom system.

d. Unloader Operation

The mechanism used for discharging radioactive material from the reactor tank has its "ON-OFF" switch and position indicator lights on the reactor top, but it is operated from the canal. If the remotely operated valve in the sub-pile room were to malfunction and stay open when the discharge tube was not in place, the water level in the tank could fall to a dangerous level in a few minutes. Interlocks are provided to insure safety, but good practice is to assume malfunction could occur.

Before the unloader can be used, the discharge chute must be cleared by the removal of the "D" piece and the steel plug. The latter is in the bottom plug. This has a special storage holder on the tank side. The beryllium "D" piece, however, is stored on the reflector to keep it deep under water during "man in tank" operations.

The handling of buckets and long extension tools, which are used in conjunction with discharges, is best learned by actual experience, so it will not be described here.

e. Lattice Work

Work in the lattice begins as soon as the upper grid is removed.

(1) Fuel Elements

Depending on scheduling, the fuel elements can be discharged and new ones loaded. The element must be placed in a handling bucket to protect it while it is discharged.

(2) Shim Rods

Movement of these rods requires special care. First, they are heavy and are best handled by the special tool which has fingers that fit into the milled upper cooling openings. Second, they may present a hazard due to the large amount of reactivity poison (cadmium) which is removed when one is withdrawn.

f. *Reactor Instrument Removal*

The reactor instrument group occasionally finds it necessary to remove some of their neutron detection instrument heads for repair or replacement during shutdown. The HP on the reactor top should monitor as these are pulled from access holes from levels near the flux zone. In some cases the insulation and dust on the wires connected to these heads is highly contaminated, and precautions must be taken. These heads are often reading quite high, and a shielded container should be ready for their disposal to avoid unnecessary personnel exposure.

g. Special Shutdown Items

(1) Man in "A" Tank

Occasionally a man is lowered via bosun's chair into the top tank section to tighten bolts, assist in experiment removal or insertion, or perhaps to do some welding. Before entry he should have removed all personal clothing, put on the necessary protective clothing, protective breathing equipment, and a pair of fisherman's waders. In addition, a lineman's safety harness must be worn with a rope attached. While the man is in the tank, the rope must be held by someone capable of supporting the man manually should the chair become disconnected from the crane or should the man otherwise get into trouble while in the tank. The constant attendance of a health physicist is required to monitor the man while in the tank. The water level is lowered for entry by opening the remotely air-operated valve located in the process water discharge line to the seal tank. The valve bypasses the level limits imposed by the seal tank weir and permits a maximum lowering of 9 ft. The air control regulator for the bypass valve is located on the south reactor instrument cubicle and its key is kept in the supervisor's safe. It may not be used without his authorization. An HP survey should be made prior to lowering the man into the tank. In case of welding in the tank, an airline respirator is required and the fumes and smoke rising from the tank are exhausted by the stack suction line ("Willie the Worm") and checked with the CAM sniffer hose.

It has been and will continue to be a standard practice for Operations Branch to conduct routine work in and on the reactor tank without processing a Safe Work Permit (SWP) for each job. Such work normally consists of refueling the reactor, handling experimental capsules, leads, and related equipment.

This practice in no way negates the requirements for continuous surveillance by responsible Health and Safety personnel as conditions warrant.

Special jobs performed in the tank by other than Operations personnel require an approved SWP. It should be noted that no one outside the Operations organization is permitted to do any work affecting the reactors or their associated facilities without first securing the approval of the responsible Operations supervisor.

(2) Communications

During periods of reactor shutdown, good communications between the different operating areas such as the canal and the reactor top, crane operator and reactor top, supervisor and top plug, supervisor and canal, etc., are vital to smooth, safe operation. Either telephones or an intercommunication system are available between these areas.

h. Upper Grid Replacement

One of the most difficult shutdown operations is the replacing of the upper grid. Before the grid is brought back from the canal, the area must be cleared of personnel and health physicists must be present. With the working platform extension doors open, the crane operator will lower the grid part way into the tank without undue exposure to engineers or technicians. It can then be transferred to the one-ton crane and lowered slowly into place. There are two grids which are used alternately during cycles. The "cold" grid should always be returned.

With the grid in place, each shim rod is raised a few inches with a hook tool and allowed to drop back into its seat to see that it falls freely. Each shim rod should only be pulled a maximum of 6 in. and only one rod at a time may be checked. Any deviation from this procedure will require prior approval.

i. Top Plug Replacement

Replacing the top plug should be done with extreme caution. As the plug is lowered, all experiment leads should be watched closely to insure that the magnets or guide supports do not touch them. After the regulating rods are connected and the manhole covers replaced, the top is ready for bolt-down. Following this, the seal water and electrical connections can be made and startup checks can begin.

j. VG Plug Replacement

Whenever the reactor goes to power, all plugs for the VG holes should be in place. Before a plug is removed, a health physicist must be present to monitor the beam being emitted. If the plug must remain out for a time, the area should be ribboned off and properly tagged. A plug should never remain out longer than necessary.

C. Experimental Facilities and Associated Health Physics Hazards

1. Introduction

There are various experimental facilities included in the MTR ranging from relatively large high flux beam holes placed directly adjacent to the reactor active lattice to both large and small facilities placed in the graphite reflector. Specialized facilities include those for pneumatic rabbits, etc. The demand for experimental space in the highest flux available initiated the modification of the active lattice and reflector areas inside the reactor vessel.

All of the experimental holes are potentially hazardous areas. The responsibility of seeing that proper shields are in the holes when the reactor comes up to power belongs to Operations. However, should Health Physics be called to monitor an experimental hole while the shielding is being changed, the HP must be sure to check the holes for all types of radiation, i.e., beta-gamma and neutrons (both thermal and fast). These radiation fields can be very directional (collimated), and careful surveys must be made so that minute beams are not overlooked. Care must be exercised in setting radiation tolerance distances and working times, so that changes in power level or external shielding do not appreciably increase radiation exposures to personnel.

All experiments pulled from the experimental holes should be monitored as they are removed from the reactor. Radiation levels usually differ from the calculated activities due to impurities which have not been taken into consideration. Special care should be taken so that dust from the experimental holes is not spread away from the reactor causing a serious contamination problem. A ribbon area should be placed around the shielded carrier receiving the experiment to prevent the spread of contamination. This also applies when dummy plugs or graphite stringers are removed from the reactor.

2. Horizontal Beam Holes (HB) (See Figure 7)

a. Introduction

Experimental holes 6 in. in diameter placed directly adjacent to the active lattice are furnished by the horizontal beam hole

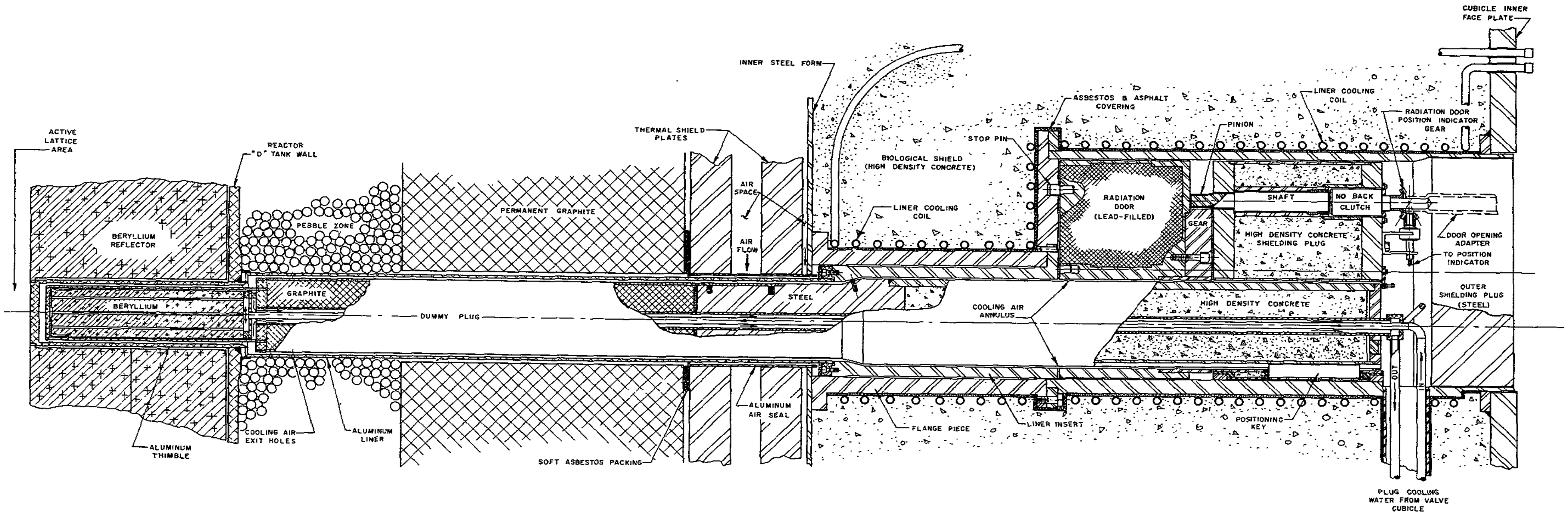


Figure 7

MTR HB-2 Beam Hole Liner and Plug

facilities, labeled HB-1 through HB-6. These holes penetrate "D" tank wall and the beryllium reflector and are isolated from the coolant water by aluminum thimbles welded into the vessel. Aluminum liners extend from the vessel wall through the graphite and thermal shields. High temperature cast steel liners (meehanite) extend from the outer face of the inside form plate to the cubicles recessed in the face of the reactor structure. These liners are wound with coolant water tubing to carry off radiation heat induced in these heavy castings.

Dummy plugs fill these holes during reactor operation when they do not contain experiments. Plug and liners are stepped to eliminate radiation streaming through the necessary clearance annuli between the plugs and liners. Construction materials of the dummy plugs approximate those materials used in the various zones through which the plugs pass. The plug tips are made of beryllium which is aluminum jacketed and water cooled.

The meehanite liner is enlarged in diameter for a distance inside the biological shield outer face. Installed in this section are three plugs or doors. Located just outside the outer end of the plug is an additional 8 in. thick solid steel outer shielding plug with a diameter to match the enlarged liner. Located inside of this outer shielding plug are two other components, the outer one a concrete-filled shielding plug, fixed in position, with a hole through which the beam hole plug passes. Located inside of it, and filling the remainder of the enlarged section, is a lead-filled steel radiation door. This door also incorporates an off-center hole to accommodate the plug, and the door may be rotated when the plug is removed to shut off radiation effectively from the empty beam hole. The reactor is, of necessity, shut down during plug removal or insertion operation.

Air flow in the liner spaces is into the graphite reflector where it is carried along with the main coolant air flow.

While the primary use of the horizontal beam hole was for irradiation of components located in the plug tips, these facilities have use as neutron beam sources.

Associated with several of the experiments are experimental cubicles located in the basement.

b. Experimental Cubicles

The loop cubicles are closed during reactor operation. They will be entered only in emergencies while the reactor is running, and then only after the proper precautions have been taken.

Entrance into cubicles is hazardous both in safety as well as radiological considerations.

(1) No maintenance work should be done on any part of a loop under pressure and temperature, particularly inside a cubicle.

(2) If it becomes necessary to do some minor job outside the cubicle, such as in a sample house, that part of the loop should be

isolated. This should be done with a blind in the line or a double block and bleeder. This type of job requires a Safe Work Permit. Most maintenance work is scheduled during shutdowns.

(3) It is seldom necessary for personnel to enter cubicles when loops are at temperature and pressure except for emergencies and special observations. However, in accordance with the Standard Practice Manual (SPM), entry requires that an insulated coat, a face shield, gloves, and boots be worn. They are located in a special cabinet on the north wall of the MTR basement. The protective clothing provides momentary protection against a shower of steam. A second man dressed in protective clothing must stand by in case of an accident.

(4) Radiation sources will usually be found in piping and tanks inside the cubicles. To comply with a Maintenance Supervision request, following shutdowns, when the cubicles are opened and surveyed, color coded survey sheets are placed at the doorway of each cubicle to show the different levels of radiation.

The color code to be used is as follows:

Uncolored	0-30 mr/hr
Green	30-100 mr/hr
Red	> 100 mr/hr with spots heavily colored to indicate sources of unusually high radiation.

Survey sheets are placed in plastic covers and clamped to the door or wall. Colors on the sheets are changed to correspond to any changes in radiation levels that are observed as the shutdown work progresses. The sheets are collected when the reactors go to power and replaced by new ones each shutdown.

Loop BIX (before ion exchange) samples are taken each shift for gross radiation readings. In addition, special samples for loop chemistry are required from time to time as requested by the sponsor. It is recommended that these two samples be coordinated so that one serves both purposes.

c. HB-1

HB-1 is occupied by an experiment that uses the facility for irradiation of components located in the plug tip. This experiment is coupled with supporting equipment located in the basement of MTR in an experimental cubicle.

d. HB-4 Crystal Spectrometer

The crystal spectrometer is an apparatus for producing a monoenergetic beam of neutrons. The neutron has wave properties, and the atoms in a crystal are arranged in an orderly array thus making such a device possible. When a neutron beam strikes the crystal, the atoms of the crystal act as scattering centers. The scattered waves interfere with one another, reinforcing or cancelling each other according to their relative phases.

Because high radiation fields are present in the crystal spectrometer cubicle, an HP survey is necessary before personnel enter. After modifications are made in the cubicle, both gamma and neutron surveys are made in the surrounding area when the spectrometer starts operating. Contamination checks in the cubicle are made when the reactor is down.

e. HB-6 - Fast Chopper

The MTR fast chopper was constructed to utilize the high neutron flux available in the MTR for the determination of the various cross sections of numerous isotopes of elements.

Two shutters are provided for controlling the reactor beam. The first consists of 3 ft. of steel which can be placed in the beam path by a horizontal movement of the tapered steel radiation door section. The second shutter is a 13 ft. tank which is filled with helium to allow the beam to emerge or which is filled with water to shut the beam off completely. The steel radiation door offers sufficient protection to allow personnel to work during reactor operation in the vicinity of the chopper for short periods of time.

The entrance stator automatic sample changer on the fast chopper was designed to handle radioactive samples. Since its installation it has proved satisfactory, and radioactive samples are handled in the system at periodic intervals. To help assure that a radioactive sample will not be removed by mistake, a log book has been provided at the chopper green shield for logging the samples in and out. Locks are provided on the sample cask, shielding door, and sample loading drive mechanism. The one key, marked "fast chopper," located in the HP office will fit all three locks. Whenever a sample is transferred from the sample charger, an HP should monitor the radiation field to assure that personnel receive no excess radiation. All sample blocks removed from the sample charger should be handled as contaminated until they have been checked.

3. Horizontal Through Hole (HT-1)

The HT-1 facility extends horizontally through the reactor tank. The plug center section is aluminum-clad beryllium and is water cooled. Radiation doors and shielding plugs similar to those in the HB facilities are used.

The interior of HT-1 is highly contaminated from previous experiments, and care must be exercised when the hole is opened to prevent contamination from spreading.

The Solid State Section, Nuclear Physics Branch, MTR Technical, uses the HT-1 hole as a source of neutrons in inelastic neutron scattering experiments. The principal of these experiments is to produce bursts of monoenergetic neutrons; scatter these neutrons from samples; and measure, by time-of-flight methods, the neutron energy change produced by the sample. The velocity selector, which consists of four thermal neutron choppers spinning in phase at 5000 rpm, is located under the shielding between the reactor and the center of the scattering chamber. The sample and counters are inside the circular shielded scattering room. The time analyzer and other electronic equipment are located in the racks near the north reactor building wall.

4. Horizontal Graphite (HG) Holes

The HG-1 through HG-4 holes extend horizontally through the permanent graphite reflector in a north-south direction. They are not fitted with shielding plugs, radiation doors, etc., due to the low radiation level that would emit from them.

HG-5 and HG-6 are horizontal beam hole facilities on the east face of the reactor and extend to the reactor tank wall. The plugs, liners, radiation doors, etc., are similar to the HB facilities.

An experiment assembled at the HG-5 beam hole is called the MTR cold neutron facility. This equipment is used to make inelastic neutron scattering measurements using an initial beam of beryllium filtered neutrons. The beam of neutrons from the reactor is filtered through two beryllium filters each 16 in. long, which allow 62 percent of the neutrons below the 0.005 eV to pass, while allowing only one in about 10^8 of the neutrons with energies above this value to pass. For the beryllium to act as such an efficient filter, it must be kept at liquid nitrogen temperature (-196° C). Both beryllium filters are contained in triple-walled containers such that the beryllium is surrounded by liquid nitrogen, and the liquid nitrogen is separated from the outer wall by a vacuum. One filter is located 3 ft. inside the reactor shielding, and the second filter is located 2 ft. outside the reactor shielding. This allows the HG-5 radiation door to be used to stop the beam when experimental changes are needed.

The radiation fields around this facility should be checked by health physics each time the shielding is rearranged.

5. Horizontal Pneumatic Rabbit Holes (HR) - Neutron Flux Facility

A general purpose neutron beam facility has been installed into the HR-4 beam port of the MTR. The plug which fits into the HR-4 liner has a 3 in. diameter hole leading up to the reactor tank. The radiation door, located at the reactor shielding face, is a revolving, cylindrical, boral clad, lead and steel shield, 1 ft. thick, through which are 1/4 in., 1/2 in., 1 in., 2 in., and 3 in. diameter holes. Neutron beams of these sizes may be obtained by revolving the door so that the appropriate hole lines up with the axis of the 3 in. diameter holes. Shielding walls of steel-encased borated paraffin enclose a volume about the exit port of about 6 ft. along the beam by 10 ft. by 7 ft. high. The neutron beam exits this shielding cubicle through a 1 ft. diameter hole in the back shielding wall and enters a beam catcher containing lead, lithium carbonate, and a cadmium-lined water bath of lithium nitrate. A gamma-ray-attenuating plug is placed inside the liner against the reactor tank. This plug is a water-cooled cylinder of bismuth metal which affords effective gamma attenuation with a minimum loss of neutron intensity.

The facility is equipped with a "high-intensity, low resolution," crystal spectrometer installed in the shield cubicle. This spectrometer produces a neutron beam of known energy containing little gamma flux for experimental purposes.

The experimental program designed for this facility includes studies of the fission process in heavy nuclei, studies of nuclear structure by measurements of the gamma spectrum emitted following neutron capture in various nuclides, and development of special nuclear particle detectors for reactor control and health physics application.

The door to this cubicle is locked and the key is kept in the Operations Shift Supervisor's office. No entry should be made with the reactor operating, and at all other times an HP must monitor entry into the cubicle.

6. Down Beam Holes (DB)

Located directly above the HB holes and the reactor first level balconies are six down beam hole facilities designed similar to the HB facilities. The liners are designed similar to the HG facilities and include radiation doors and inner and outer shielding plugs.

The relatively large expense of design and fabrication of experiments to be placed in these facilities, coupled with the demand for irradiation space with higher fluxes, has resulted in slight use of the DB holes. The hazards connected with these facilities would be the same as for the horizontal beam holes.

7. Vertical Graphite Holes (VG)

As the term VG implies, these facility holes are positioned vertically in the graphite reflector and extend to the reactor top. The holes pass through the concrete biological shield where they are fitted with stepped steel liners and extend into either the solid graphite reflector or the pebble zone. The VG plugs, used to fill the holes in the absence of experiments, are made with a high-density concrete-filled steel upper section and graphite lower sections. Air leakage, if any, flows from the reactor top, between the upper section plug and the steel liner, and into the plenum above the graphite reflector.

When these VG shield plugs are pulled, an HP should be present to monitor the radiation fields. If they are pulled when the reactor is operating, a high gamma and neutron beam will be encountered.

The capsules used in the various experimental facilities are termed "rabbits". Some VG holes are adapted for rabbit irradiation facilities, and it is necessary to monitor as they are received in the catcher.

8. Other External Hole Facilities

The HR-3 and HR-4 facilities are horizontal beam holes terminating at "D" tank wall and are located on the west face of the reactor structure.

Two holes, used for reactor control instruments, are the HI-2 and HI-3 facilities which extend through the permanent graphite. These holes are used for the reactor control system.

Penetrations in the top of the reactor structure extend to 6 in. pipe thimbles welded into the two 24 in. exit water lines. GT-1 serves the southwest exit water line and GT-2 serves the northeast line. It was anticipated that these would be used for experiments requiring a pure gamma field. Liners in the concrete, placed adjacent to the 24 in. pipes and the GT thimbles, are termed GM-1 and GM-2. These facilities are used for the measurement of gamma radiation emitted from the N-16 in the process water after it leaves the reactor vessel.

Instrument holes extending from the top of the reactor structure to the pebble zone are labeled VN-1 through VN-6. These have an inside diameter of 3 in. and may contain an ion chamber used in reactor control. (see figure 8).

A thermal column facility, encompassing a large number of individual holes with neutron and gamma radiation levels lower than those existing in the permanent graphite reflector, is installed on the east face of the reactor structure. It is composed of a 6 ft. sq. column of graphite extending from the outer face of the biological shield to the outer face of the outer thermal shield plate.

A 3-in. thick lead plate, placed between the permanent graphite reflector and thermal column, reduces the gamma radiation emanating from the permanent reflector. This plate (called a "neutron window") is positioned in an opening cut in the outer steel thermal shields. Located between the thermal shield plates is a 1/4 in. thick boral curtain which may be raised or lowered into position and which captures neutrons emanating from the graphite reflector. This is the "neutron curtain". Normally, it is left down and out of the way.

The HG-9 facility is a large stepped, rectangular hole, 10 in. horizontally by 16 in. vertically at the inner end extending from the east face of the reactor structure through the thermal column and graphite reflector to the reactor vessel wall. The entire plug is made of graphite. A perforated aluminum liner bridges the pebble zone between the permanent graphite and "D" tank wall on the HG-9 facility.

T2H-6 is the most commonly used hole in the thermal column. Fission chambers are inserted into the hole, irradiated, and checked for activity.

Contamination and radiation will be encountered in the process of calibration, necessitating an HP ribbon around the area. No one

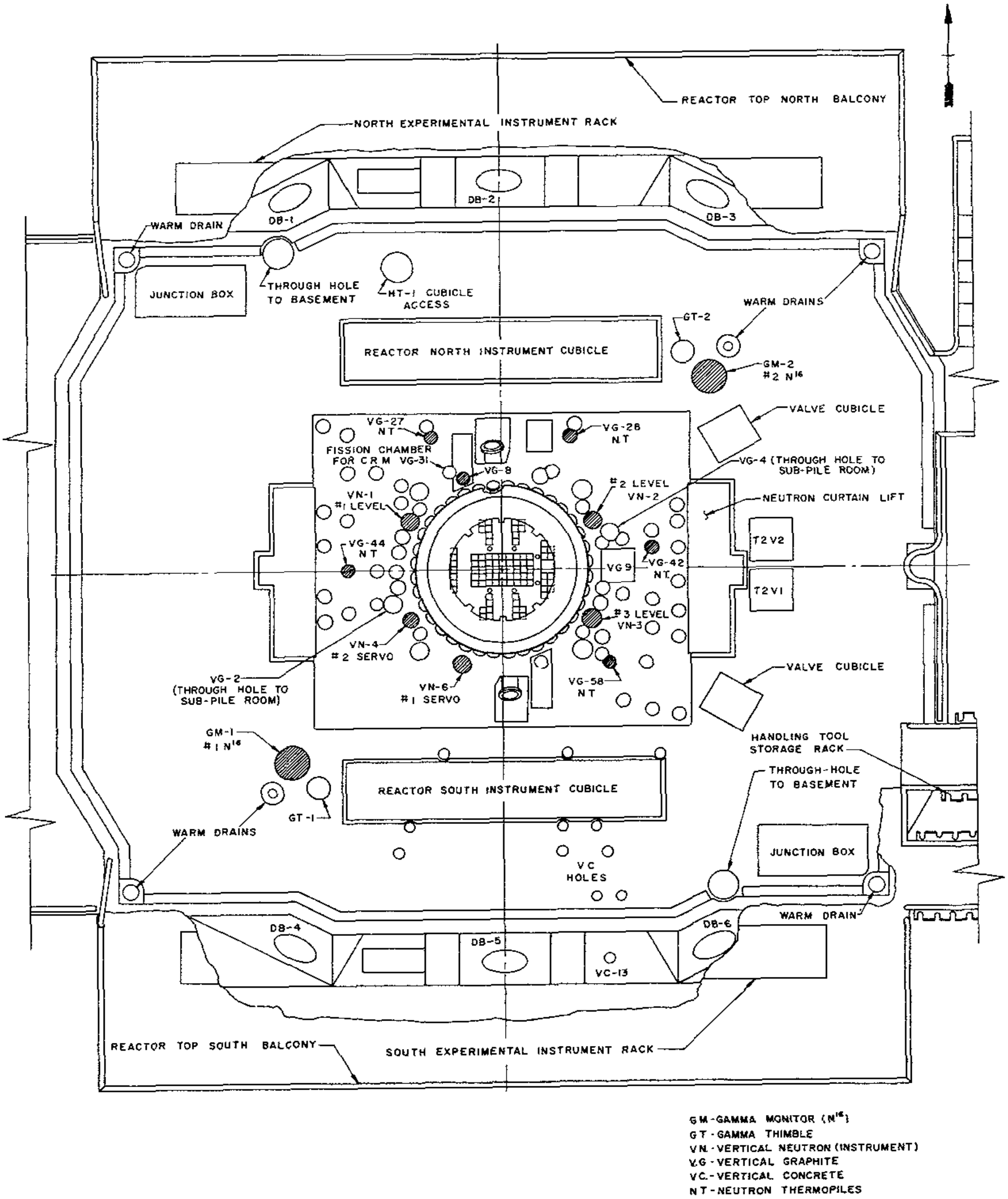


Figure 8

MTR Reactor Structure
(Top Plane)

should be allowed to walk through the neutron beam streaming from the hole. Neutron dosimeters and film badges with neutron film should be worn by everyone working around the facility. An HP is to provide continuous monitoring while this work is being performed.

Other facilities in the thermal column, which extend horizontally to the thermal shield face or downward to the thermal column from the top of the reactor structure, vary in size from 4 in. to 12 in. square. For a complete list of all irradiation facilities see Table 9 of report IDO-16871-2.

9. Hydraulic Rabbit Facility

A device for loading, insertion, and removal of small samples into and out of the reactor with the reactor operating is termed the "hydraulic rabbit facility". This facility is located in the rabbit canal, an 8 ft. deep extension of the main canal on the west side of the reactor structure in the basement. Four tubes, two of which have a bore of about 1 in. and the other two a bore of about 1-5/16 in., extend from a loading station in the rabbit canal horizontally east and then turn up and penetrate the bottom plug. VH-1 and VH-2 are the two smaller facilities and are located in the beryllium reflector on the east side of the active lattice. The other two are termed VH-3 and VH-4 and extend into the reflector holes in the south side of the active lattice that were originally intended for the two south regulating rods. The VH-3, or southwest hole, has been converted to an in-pile experimental facility.

These facilities utilize the process water pressure from the Experimental Cooling Loops to force the capsule into the reflector and utilize reactor tank water pressure to eject them back to the rabbit canal. The capsules are termed "rabbits" and are about 3 inches long.

Constant monitoring is necessary at the rabbit canal when the rabbit is to be discharged and also at the main canal for decapsuling. As the rabbits are discharged into the rabbit canal, they should be visually inspected for air bubbles which could cause high level air activity.

Rabbits transferred by shuttle tube to the main canal and decapsuled require constant health physics monitoring until they have been placed into a shielded holder or left in the canal for storage. The HP is to keep in mind the possibility of a "floater" and be sure a catcher is ready to hold it under the water until the radiation field can be determined by raising it slowly toward the surface.

10. Pneumatic Rabbit Facilities

A facility similar in intent to the hydraulic rabbit facilities, but operated by compressed air or vacuum, is the pneumatic rabbit facility. There are two tubes which pass through the beryllium reflector in a north-south direction on the east side of the active lattice. The size of the tubes limits the diameter of the capsule to about 1 in. with a length of 3 inches. Due to the high flux heating of these samples and the relative inefficiency of air cooling, the sample weights and capsule weights have to be restricted to a total gross weight of 25 g. While it was originally intended that the facility tubes be extended to laboratories located in the wing, the high cost, possibility of contamination, and shielding problems associated with the design and use of such facilities have not allowed this expansion.

A facility has been installed in the decontamination room to utilize the pneumatic rabbit facilities. The controls and the catcher are in a shielded, negative pressure glove box with a Tracerlab monitoring head mounted in the glove box to monitor the irradiated capsules.

Due to the foreign material in the piping, contamination will likely be a problem, requiring a survey before the experiments or materials used in the glove box are removed from the area. An air filter system has been provided in the piping system and is located by the north side of the reactor on the main floor.

11. In-Tank Facilities

a. Active Lattice Facilities

Special "L" pieces made of beryllium and resembling a fuel element occupy the "4" and "5" rows in the lattice and are sometimes modified to hold experiments. Others have been replaced with aluminum pieces that are drilled to hold capsules. These consist of three types: a single 5/8 in. center hole, an X-basket hole in each quadrant, and a single X-basket in a center hole.

b. Capsules

Capsules are placed in X-baskets and then inserted into holes in the "A" pieces, which are beryllium sections that occupy the outer edge of the beryllium reflector. The X-baskets are removed and replaced with a hook tool. After irradiation, the capsules are sent to the canal in a discharge bucket through the loading chute.

c. Lead Experiments

This type of experiment is an instrumented capsule with thermocouples, heater leads, and possibly, gas pressure supplied. The capsule portion is inserted into a hole in the "A" pieces with the lead extending out of the tank through a spool piece port.

(1) B-4

The B-4 in-tank piping, is located in the B-4 beryllium piece in the northwest section of the reactor tank. The piping extends up and out through the spool piece on the north side, across the floor and down through the reactor shielding to the cubicle. Formed, lead shielding is placed over this piping where it crosses the floor.

(2) GEH-B3

This experiment is located in the northeast section of the reactor tank. The piping extends down through the B-3 beryllium piece and out of the tank through the tank spool piece on the northeast side and goes through the VG-4 hole to the sub-pile room, into the canal and out to the pumps south of the canal.

To be discharged to the canal these experiments have to be raised and placed in special discharge buckets. High radiation fields will be encountered as any of these experiments are transferred to the discharge bucket, especially B-4. The HP should make sure these experiments are raised no higher than necessary, that they are transferred as quickly as possible, and that a minimum number of personnel are present.

(3) L-42

The southwest shim-safety rod, termed L-42 position, has been removed, and this hole is used for in-pile experiments. L-42 experiment is a re-entrant type with leads and cooling medium access below the reactor bottom. The piping then goes into a cubicle.

(4) VH-3

This experiment occupies the southwest spare regulating rod space and is an in-pile experiment. It is a high pressure system with the coolant water flowing around the experiment and circulating through the system.

D. MTR Process Water (see Figure 9)

1. Process System

The MTR is cooled and moderated with demineralized light water contained in a nearly closed system. When the reactor is being operated, the water is forced through the core at a flow rate of 20,000 gpm. The heat picked up in the core is then transferred to a secondary cooling system from which it is dumped to the atmosphere.

In order to trace the system through, let us begin arbitrarily at the bottom of the reactor tank where the water exits through two 24 in. diameter pipes. These head into a single 36 in. diameter pipe at the lower end of a pipe tunnel colloquially known as the "snake pit". Within the snake pit the 36 in. diameter line runs north rising as it goes to a point outside the reactor building line where it is reduced to a diameter of 30 inches. The 30 in. line continues northward for a short distance then turns to run eastward through a pipe tunnel which continues into the Process Water Building.

From the pipe tunnel it emerges into the seal tank room occupying the northeast corner of the Process Water Building and enters the 17,000 gallon seal tank. The seal tank functions as a flow divider. Four lines exit from the seal tank: (1) a 36 in. diameter

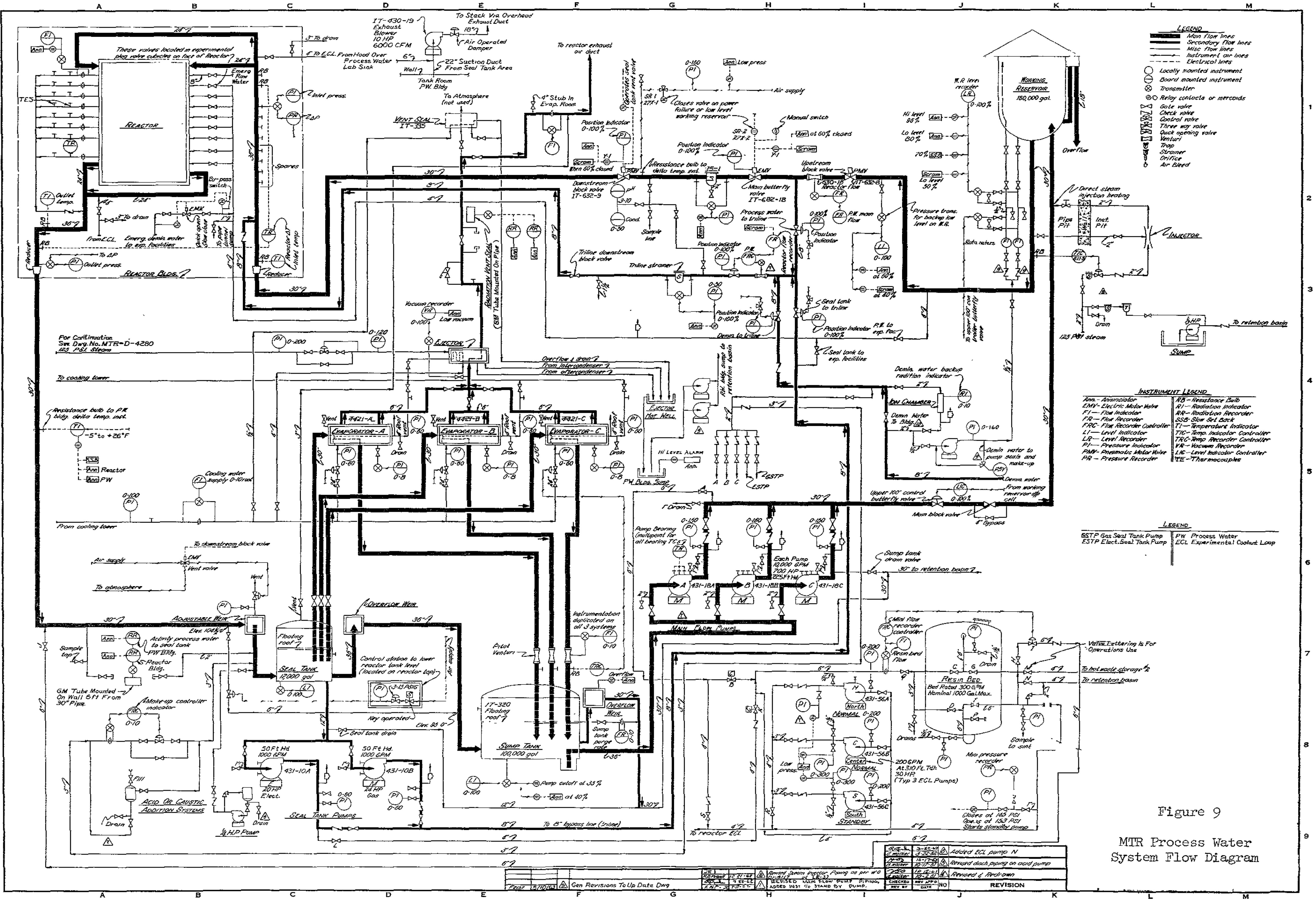


Figure 9

MTR Process Water System Flow Diagram

overflow to the 100,000 gallon sump tank and (2) three 30 in. diameter lines through which water is drawn into the three flash evaporators in the top room of the Process Water Building. A system of steam ejectors maintains a vacuum of approximately 23 in. of mercury in the evaporators. This is enough to draw water from the seal tank, provided there is at least 8.7 feet of water in it, and out through spray nozzles into the low pressure region of the evaporators. The vapors formed due to the low temperature, low pressure boiling are condensed in the upper part of the evaporators. The resulting heat is transferred through the condenser coils to the secondary cooling system. See Figures 10, 11, and 12. Part of the water contained in this secondary system is then evaporated to the atmosphere through a cooling tower.

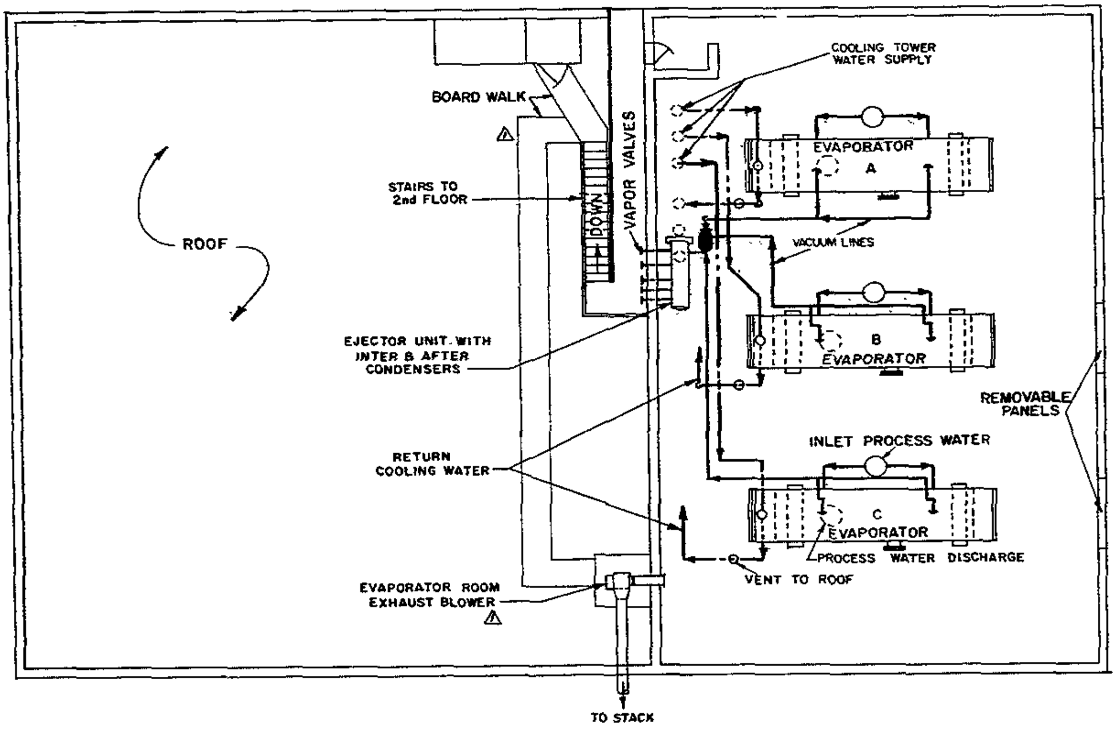


Figure 10

MTR Process Water Building
Second Floor Location Plan

As the water flashes to vapor in the evaporators, radioactive gases present in the water come out of solution and are subsequently removed through the ejectors to a four inch line leading to the MTR stack (a three inch vent line from the seal tank also ties into this line).

The condensate collects in the three 24 in. diameter drain lines leading down to the sump tank. Although the water levels are maintained about 26 feet above the sump tank water level by the vacuum in the evaporators, there is a net transfer of water to the sump tank.

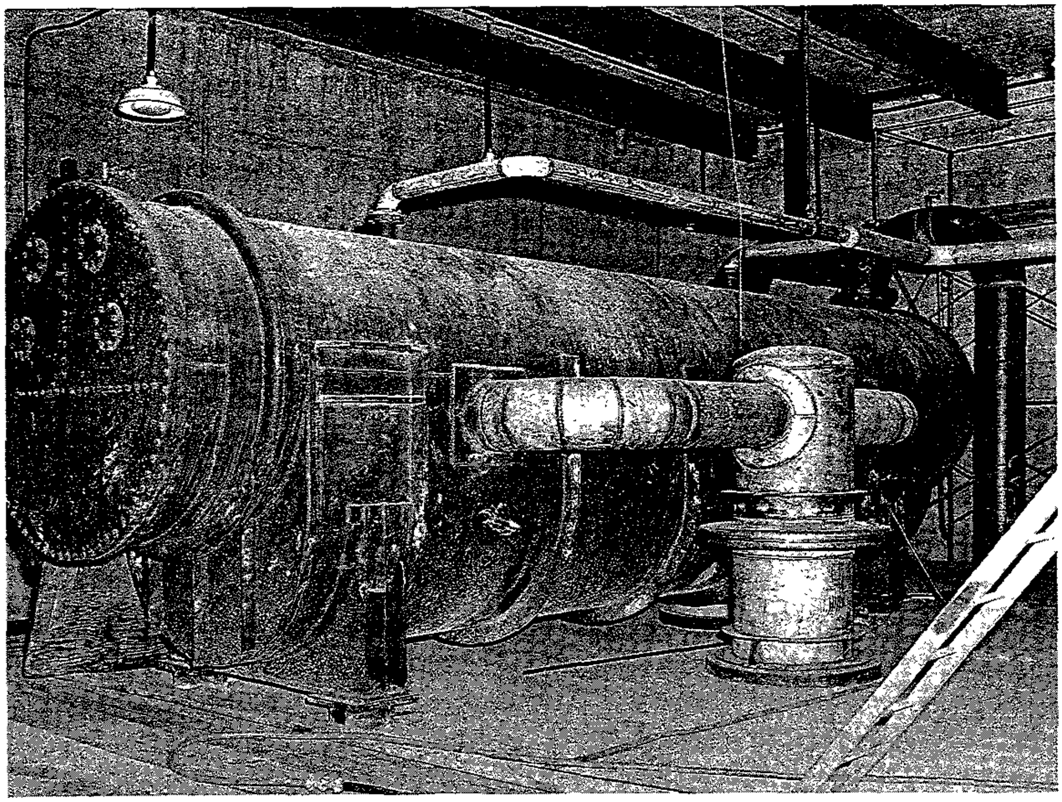


Figure 11

Exterior View of an MTR Process
Water Flash Evaporator

The inlet header and its distribution arms enter the side. Vacuum lines leading to the ejector leave the top. Cooling tower water lines and the vent through the roof can be seen on the far end.

From the sump tank there are three outlets. One line leads to an overflow weir, and from there a 30 in. diameter line runs directly to the retention basins. During normal operation about 100 gpm of fresh demineralized water is being added continuously to the system, and that much process water is displaced through a second line out of the sump tank through a flow meter and out to the retention basin. The third is a 36 in. diameter line leading to the inputs of the three 700 hp main sump pumps which elevate the main flow to the 160,000 gallon overhead working reservoir. From the overhead reservoir the water returns in a 36 in. diameter line under the seal tank room, through the pipe tunnel, back into the reactor building snake pit where it goes first into a 36 in. diameter pipe and then into two 24 in. diameter pipes which enter opposite one another near the top of the reactor tank. This completes the cycle for normal operation.

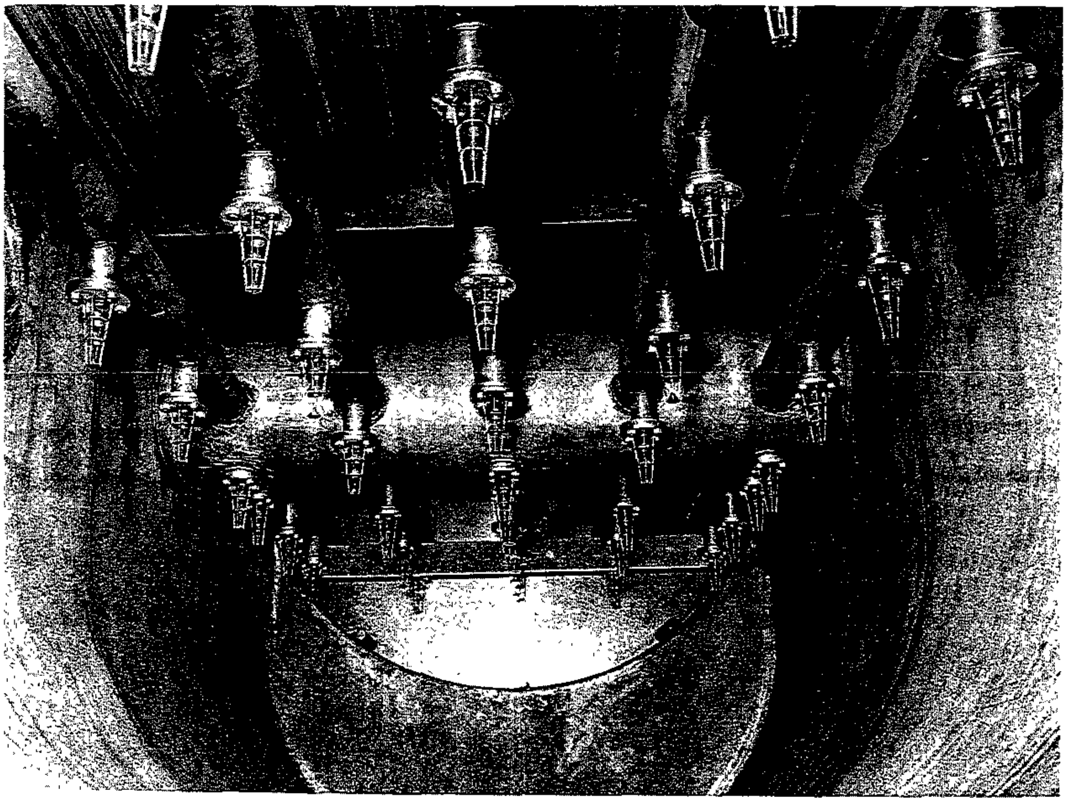


Figure 12

Interior View of an MTR Process
Water Flash Evaporator

One inlet header and distribution lines with spray nozzles can be seen. Cooling pipes on which flashed vapor recondenses are seen in the upper section.

When the reactor is shutdown for fuel change or to change out experiments, the process water is flushed out and replaced by demineralized water. The fresh water is introduced at the Process Water Building into an 8 in. by-pass or triline. The triline parallels the main process lines to the snake pit where it is connected into the 36 in. diameter inlet line. The sump tank, the overhead reservoir, and the flash evaporators are effectively isolated; and the flush involves only the triline, the reactor vessel, the 36 in. to 30 in. outlet line and the seal tank. The flush operation normally requires about 70 minutes of time and 50,000 gallons of demineralized water. When it is complete, the fresh water continues to be circulated through the by-pass system at a flow rate of 500-700 gpm.

There are three auxiliary systems associated with the process water system, the by-pass resin bed, the experimental cooling facility, and the process water to experimental facilities.

a. The By-Pass Resin Bed

An adjunct to the main flow system which is used during some cycles is the by-pass resin bed. This contains both cation and anion resins for the purpose of removing fission and corrosion product activities from the process water. During reactor operation, the input for the resin bed is normally tapped off just down stream from the main sump pumps, and the output is divided between the Experimental Cooling Loop (ECL) and a 6 in. line returning to the main flow system just upstream from the adjustable weir before the seal tank. When the reactor is shutdown and it is desired to keep the resin bed in operation, the output is routed entirely through the ECL.

b. The Experimental Cooling Loop

It is necessary to maintain coolant flow to some of the pumps and heat exchanges in the reactor basement loop cubicles. A 4 in. diameter supply line has been provided for this purpose. Input to the ECL may come either from the resin bed effluent when it is being operated, from the seal tank drain, or from the downstream side of the main sump pumps.

c. The Process Water to Experimental Facilities

This is a 4 in. supply line which takes process water from a point upstream of the upstream block valve and makes it available for flow through the plug experiments. This water is returned to the 36 in. diameter process water outlet in the snake pit. At shutdown this system may also take its supply from the seal tank and be flushed out with that part of the main system.

2. Radiation Monitors

There are four radiation monitors associated with the MTR process water systems. Although they are intended primarily for use by Operations, the information produced by them is also valuable to health physicists in assessing the hazards which may be associated with abnormal activity in the process water.

a. The Seal Tank Monitor

A sample of process water is drawn from the 30 in. diameter inlet line in the seal tank room at the level of the adjustable weir. It is passed through the center of an ionization chamber located against the north wall of the room and dumped back into the down-comer from the adjustable weir. This sensor cannot be calibrated effectively because it is located where background variations affect it. The information from it is conveyed to a recorder in the Process Water Building control room and to a slave recorder in the reactor control room. A high radiation signal from it may indicate gross contamination of the process water, if the reading is continuous, or that hot particles are circulating through the system. The latter condition will be indicated by spikes on the recorders.

b. Vent Seal Radiation Monitor

A continuous sample of the steam ejector off-gas is taken just downstream of the quick opening valve between the ejector and the vent seal. This sample is taken through the ion chamber, the resulting information being presented to a recorder in the process water control room and a slave recorder in the reactor control room. A high reading on this monitor may be the first indication of a fresh fission break in the reactor. An increase in stack gas activity may be regarded as confirmatory evidence.

c. The Demineralized Water Backup Monitors

Although the 8 in. line from the Demineralizer Building can be isolated from the process water lines by the "demineralized water to building" block valve, there is a make-up flow of demineralized water to the system, as mentioned previously, and the line must remain partially open. If, for any reason, the demineralizer pumps fail to maintain adequate pressure, process water may back up into the demineralized water system. For this reason, a sample from the upstream side of the block valve is passed through the center of an ion chamber which makes information for a recorder located in the process water control room. The block valve is, in fact, normally closed during reactor operation; and the 100 gpm purge is routed entirely through the chamber, which is mounted on the north wall of the Process Water Building.

A similar monitor is mounted in the reactor wing basement. It is located on the south wall of the library vault and takes its sample from a 3 in. line carrying demineralized water eastward into the reactor basement. Some systems such as the hydraulic rabbit facilities and the unloader are normally supplied by demineralized water but may use process water when necessary. Again if the demineralized water pumps fail to maintain enough pressure in that system, there is a possibility of getting radioactive water in the demineralized water lines. This is true even though there are what are normally considered adequate valves and check valves where the two systems tie together.

With some frequency someone will carry a calibration source near the ion chamber. When this happens, a horn sounds at the west end of the reactor wing. An annunciator is actuated in the reactor control room where a ratemeter is also located. Although a large percentage of the alarms from this monitor can be traced to external sources carried past it, the Health Physics technician should always investigate their causes. The wash basin near the reactor canal is supplied from demineralized water, and on one occasion the canal operator quite innocently washed his hands in process water.

3. Process Water Building Facilities

The Process Water Building is located east of the reactor building. The office area is maintained as a clean eating area for working personnel and has a separate air system in case of high air activity in the rest of the building.

a. Pump Pits

High concentrations of air activity will be encountered in pits containing pumps, which circulate primary cooling water, while the reactor is at full power and immediately following shutdown. Normally the hatch covers are raised about six or seven hours after shutdown to check the air activity.

The air activity is usually dispersed by this time, and workers can enter the pits after the pits have been monitored by the HP and instructions given to the maintenance personnel as to the work restrictions. Special precautions should be taken if the pumps are to be opened as the inside will be highly contaminated.

Blotting paper should be laid down around the hatch openings to prevent the spread of contamination, and the areas will be ribboned off.

Another pit is the by-pass piping tunnel where a strainer is located in the line. This strainer is periodically checked and cleaned by the maintenance people. The same rules apply as in the primary pump pits.

The clean up resin bed and the experiment cooling loop (ECL) pumps are located in the basement of the Process Water Building. The reactor resin bed (cation) can have a 300 gpm stream flowing through it which will remove most of the radioactive fission products from the process water.

High radiation fields are generally encountered around this system piping and should be monitored. When the resin reaches a point where the clean-up from circulation is no longer effective, it is pumped through a hatch on the main floor and into the tank that is used to haul the hot waste storage water. During this process, constant monitoring is required, and occasional checks should be made to assure containment of contamination.

The ECL system provides process water to the reactor basement where experiments draw from it for heat exchange and pump cooling.

b. Evaporator and Seal Tank Rooms

It has been found that very high air activity can be present in these rooms. No particular reason or time for the activities to be present has been identified, except that high air activity may exist when the reactor is up to full power. Checks on air activity should always be made before work is begun in these rooms. When the air activity in the rooms is high, personal contamination can be expected; therefore, no personal clothing should be worn, even under Anti-C clothing.

High activity sources in the process water system may lodge in the PW lines, so constant monitoring should be maintained when anyone is in the seal tank or evaporator rooms. A monitron in the evaporator room may serve as a constant monitor. The monitor should be adjusted each time it is to be used for constant monitoring, and care should be taken to see that it is switched to warm-up and the alarm shut off whenever each monitoring job is completed.

c. Overhead Working Reservoir

The reservoir is a 160,000 gallon tank that serves two purposes:

(1) To pressurize the primary water system to approximately 60 pounds psi.

(2) To provide emergency cooling for the reactor in case of primary pump failure.

The inside of the reservoir is highly contaminated. A high percentage of the contamination is low energy beta which will not penetrate the self-reading dosimeter. There may be sources of high radiation circulating in the primary cooling system which can become lodged in the reservoir. These sources may be detected through the tank wall while climbing the ladder or walking around the catwalk. They become more evident if the water level is lowered in the reservoir.

If entry is made into the reservoir during shutdown, workers should wear double Anti-C's, rubber boots, gloves, and a safety belt. Full face canister type masks should be worn for respiratory and visual protection. Each person should be equipped with a high range dosimeter. The HP monitoring the job should have two meters in case one fails and should watch the exposure time of each individual closely. In addition to the HP monitor, there should be a second HP on stand-by at the bottom of the ladder. The Maintenance crews should place all contaminated equipment in new plastic bags before lowering it from the reservoir.

Two facilities connected with the reservoir and inside the reservoir fenced area are the reservoir water level instrument pit and the pit that allows access to the primary water lines at the base of the structure. Both of these facilities must be monitored by the HP before entry by the workman is authorized. Both are sources of radiation and loose radioactivity.

E. MTR Exhaust System

1. MTR Plant Exhausts

There are three active exhaust systems connected to the MTR Fan House and discharging through the MTR stack. These systems are the Process Water Building vent, the vent scrubber exhaust, and the reactor exhaust. In addition, a fourth system is connected to the Fan House, but it is no longer in use. Since this latter system was designed specifically for the Aircraft Nuclear Propulsion (ANP) experiments, it most likely will not be used again.

a. Process Water: Flash Evaporators

The MTR fuel assembly is cooled by demineralized water passing directly through the reactor core and between the fuel element plates.

This contaminated cooling water is processed continuously at the Process Water Building. During the process, a portion of the water is passed to the flash evaporators where it vaporizes and causes any gases that may be present to come out of solution. The gases are removed through steam ejectors and pass to the MTR Fan House through a large venting duct. In addition, a vent line from the seal tank ties into this duct. A slight hazard exists if radioactive particles enter the atmosphere from this system.

b. Vent Scrubber

The vent scrubber is a system of Raschig rings and a caustic scrubbing solution. Contaminated air is passed into the scrubber tank, up through the rings and solution, and is discharged to the vent scrubber blower in the Fan House, and out the stack. The vents that are connected to the scrubber are those from glove boxes and the alpha hot cell in the Reactor Building wing laboratories and a secondary vent from the Hot Cell Building. The wing labs also contain hoods for experimental work. These hoods are vented through fiberglass filters to the fan loft of the Reactor Building wing and then through high efficiency filters to the atmosphere through a stack attached to the west side of the Reactor Building. Because of the filtering of the hood vents and the type of work done in the hoods, no hazard is expected from radioactive particles from this system.

The vent from the Hot Cell Building through the vent scrubber system is a secondary venting line. For normal operation, the vented air from the hot cell is rough filtered and then exhausted through an absolute filter to the atmosphere. For special operations with unusual sources of contamination, the vacuum line from the vent scrubber is also used. This line contains a small absolute filter preceding the scrubber system. The vent scrubber exhaust is continuously monitored at the Fan House for particulate and gaseous activity.

c. Reactor Structure

In addition to the water cooling of the reactor core, the thermal shields and graphite zones of the reactor are cooled by an air stream. Air is taken directly from the Reactor Building, filtered, passed down through the thermal shield of the reactor top and sides, up through the bottom thermal shield, through the permanent graphite blocks and the graphite pebbles, and is exhausted to the reactor air exhaust plenum. From the plenum, the air is exhausted to blowers in the Fan House and out. The air constituents and dust could potentially be a hazard. The prefiltering reduces the amount of dust, and the major activity in the effluent air gases is the inert argon-40.

d. Loop Cubicles

Connected to the reactor air exhaust plenum, that is positioned just outside the Reactor Building basement, is the exhaust from the experimental cubicles. Each of the cubicles can be highly contaminated so that each is maintained under a negative differential pressure. The exhaust from this system and from the reactor air cooling system is not filtered before passing to the MTR stack. The reactor exhaust is monitored continuously at the Stack Monitor Building for particulate and gaseous activity.

2. Experiment Cubicle Exhausts

The experiment cubicles at MTR are contaminated. This condition is a result of failures, changeovers, modifications, and maintenance of the experiments. In addition, some cubicles are contaminated from experiment coolant vents and drains. Sampling stations are also generally contaminated. The cubicles and sampling stations are normally kept under a slight vacuum to reduce the possibility of contamination spread.

The MTR cubicle exhaust system was added as cubicles were added. This system is presently being evaluated, but it is estimated to provide 1/4 inch of H_2O vacuum to the cubicles and sampling boxes. Air flow through the exhaust ducts is about 2000 to 4000 cfm. The exhausts are generally located overhead in the cubicles and sample stations.

The cubicle exhausts do not contribute much radioactivity to the plant effluent unless a high pressure steam leak occurs and causes radioactivity to be sprayed into the cubicle atmosphere.

3. Fan House Operation (see Figure 13)

Positive displacement blowers are located in the Fan House which draw cooling air through the reactor graphite and discharge it up the stack at 1800 lbs. per minute. When these shut down, small units (400 lb/min) start automatically to maintain a minimum flow and prevent reverse air flow out of the reactor. Loss of the main blowers (air flow or reactor vacuum) would initiate a reactor setback. Also, within this Fan House are exhaust blowers for the MTR wing laboratory hood vent scrubber system and radiation monitor recorders for exhaust air and plant waste waters.

While the reactor is operating, high levels of air contamination are found in the fan rooms. The fans are contaminated internally and are sources of radiation. When the reactor is shut down and entry is required for maintenance work, the HP should monitor the rooms for air activity and radiation before anyone enters.

If the CAM in the Fan House indicates a high level of air activity, and after determining if it is caused by an inversion, the HP should check around the fan room doors with the CAM sniffer hose. The doors do not provide an air tight seal and air will leak out. Normally the door is taped to prevent this.

4. Procedure for Reporting Reactor Airborne Effluent Alert

Because of the dangers of effluent release to other installations caused by fission breaks and other unplanned releases, the U.S. Atomic Energy Commission, Idaho Operations Office (IDO) Health Physics has requested that they be alerted when the MTR gaseous release activity exceeds 20 times normal output. Therefore, the stack gas monitor has a set point adjusted to sound an annunciator in the control room when this output is exceeded. Whenever effluent release rate decreases to a value below 20 times normal, Operations will call IDO and call off the effluent alert.

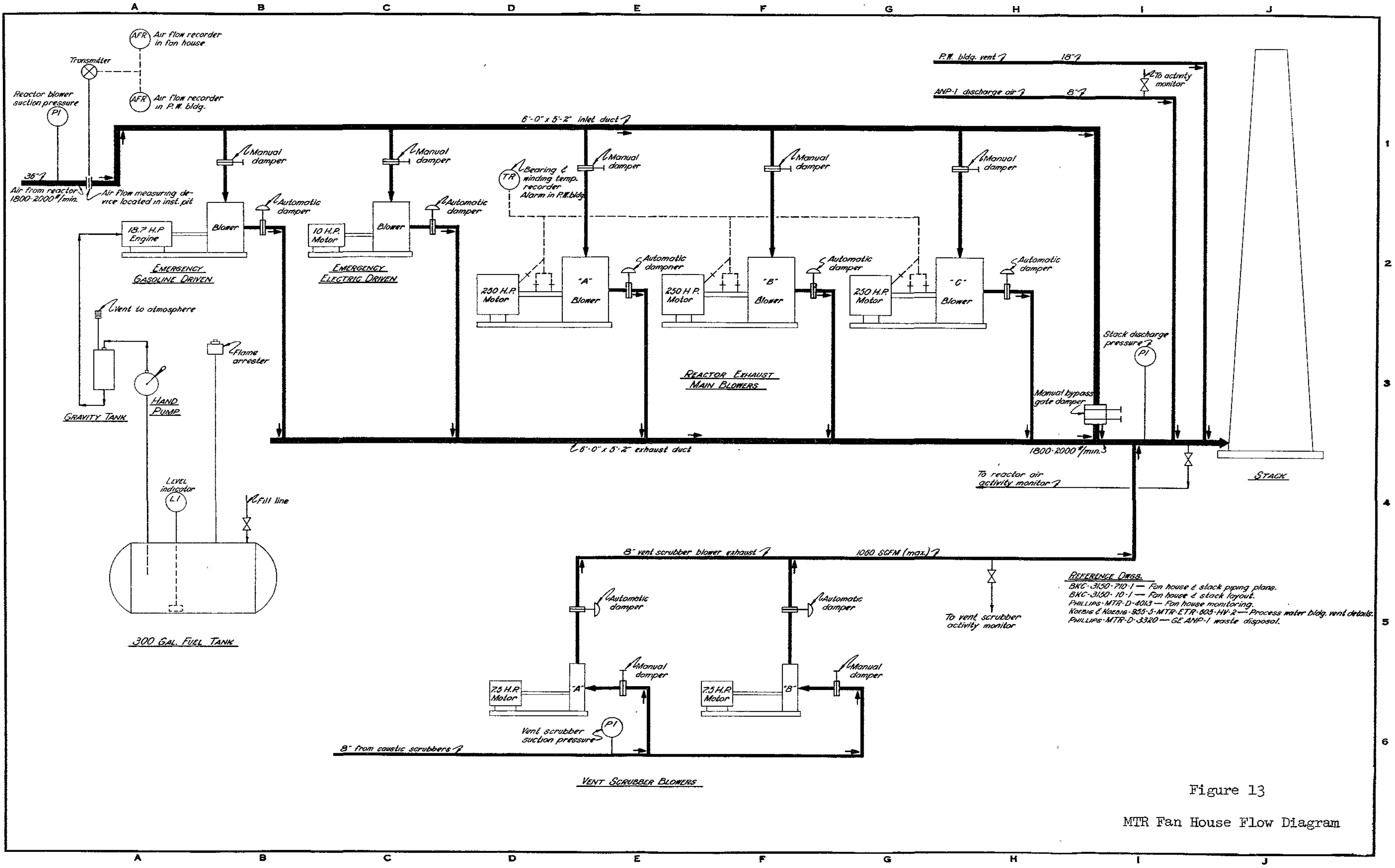


Figure 13

MTR Fan House Flow Diagram

F. Radioactive Liquid Handling System

1. MTR Liquid Waste Sources

The MTR contains three separate drain systems besides the sanitary sewer system. Each of the three contribute water to the effluent waste system at a different point of entry.

a. The Warm Drain System (see Figure 14)

The warm drain system is made to accept a continuous flow of waters intended to remain quite low in specific activity. A major source is the system of overflow drains along the canal parapet. For others, see the referenced drawing.

The low point of this system is the process sump. Water for it is pumped directly to the retention basin without sampling. The canal water is normally sampled once each week and counted for gross gamma and gross alpha activity.

b. The Hot Drain System (see Figure 15)

The hot drain system includes the floor drains throughout the Reactor Building. This is normally a low volume system, the lowest point of which is the hot drain tank under the basement floor on the west side. When filled, the contents of this tank are pumped to catch tank #1 or #2.

The hot drains from the MTR Wing are routed to catch tanks #3 and #4. Those from MTR 661, the new alpha laboratory, are routed directly to the hot storage tanks.

c. The Hot Experiment Drain (H.E.D.) System (see Figure 16)

Certain drains within the experimental loop cubicles are included in a new system leading to a tank located under the southeast stairwell. When this tank is full, its contents are pumped directly to one of the hot storage tanks.

d. ETR Wastes

There are two drain systems at the ETR, the warm and the hot. Effluent from the warm drain system is pumped to the retention basin. That from the hot drain tank is pumped to one of the MTR Hot Storage Tanks.

2. MTR Radioactive Liquid Handling System (see Figure 17)

The yard system for liquid waste handling at the MTR is shown on the reference drawing. It consists of four 1500 gallon catch tanks, two 7500 gallon and two 9000 gallon hot storage tanks and two 320,000 gallon concrete retention basins.

a. MTR Catch Tanks

Water accumulates in a given catch tank until it is full. The process water operator then diverts the input to another tank and brings a bottle of water representative of that in the full tank to

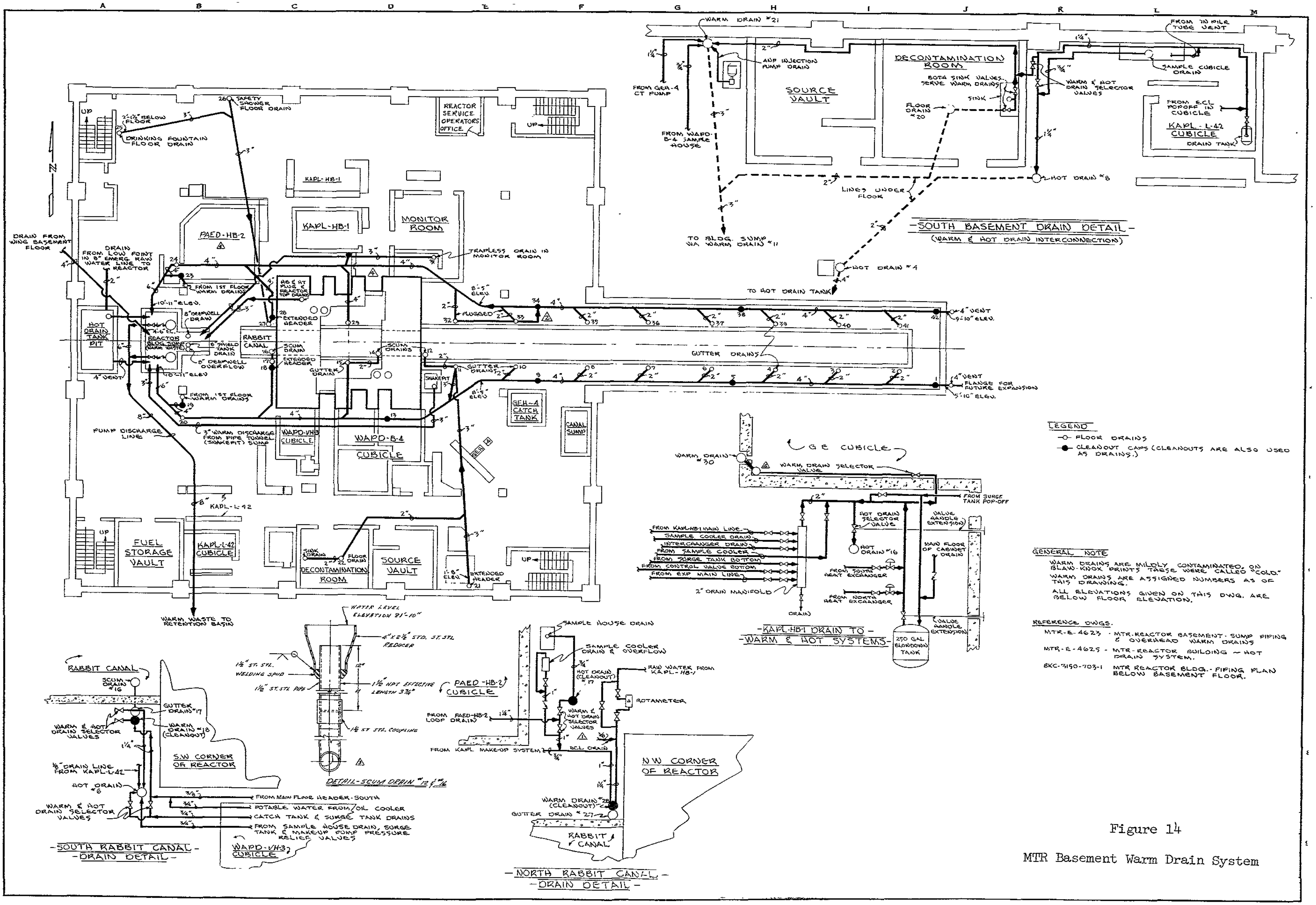


Figure 14

MTR Basement Warm Drain System

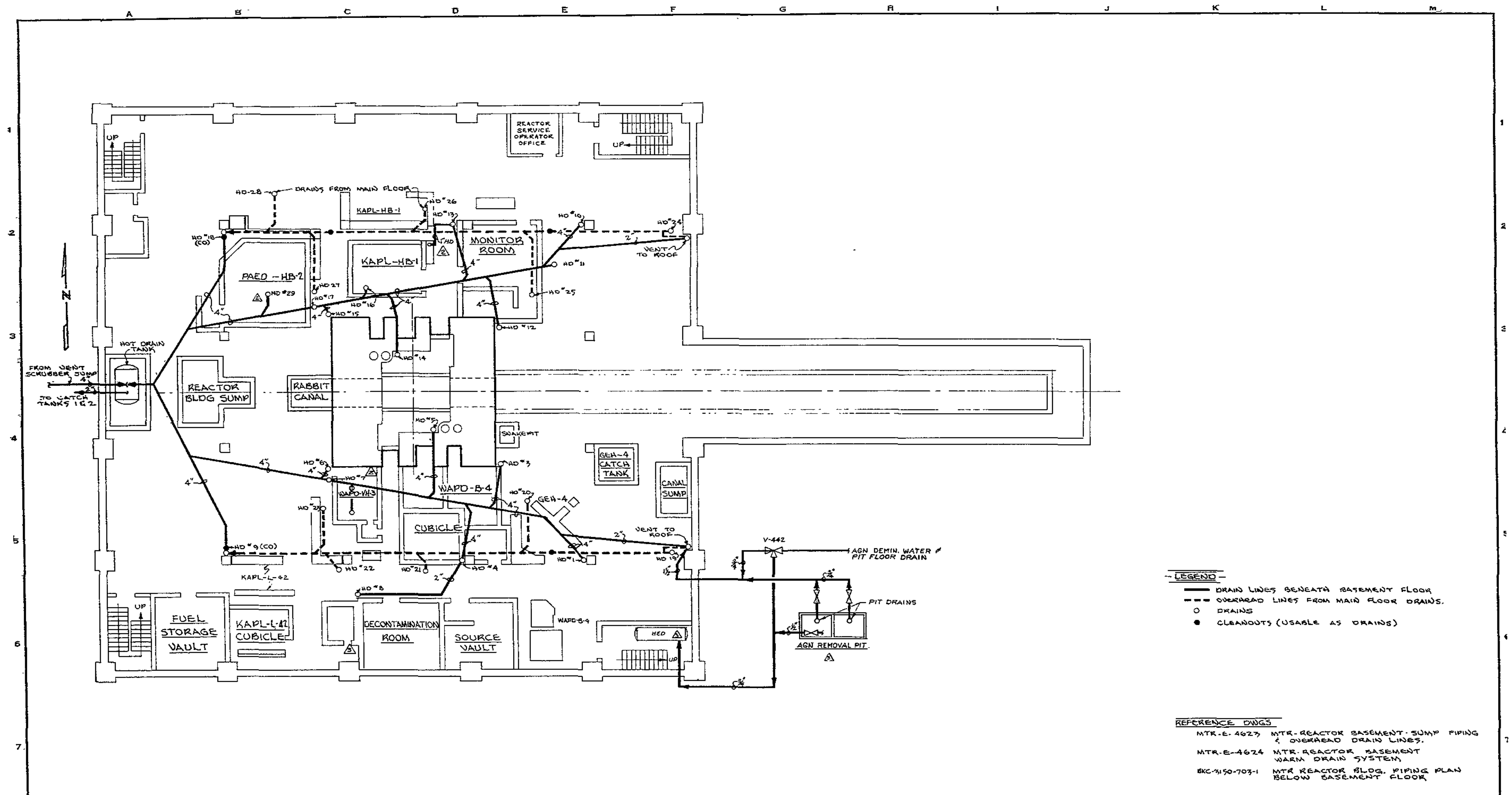


Figure 15

MTR Building Hot Drain System

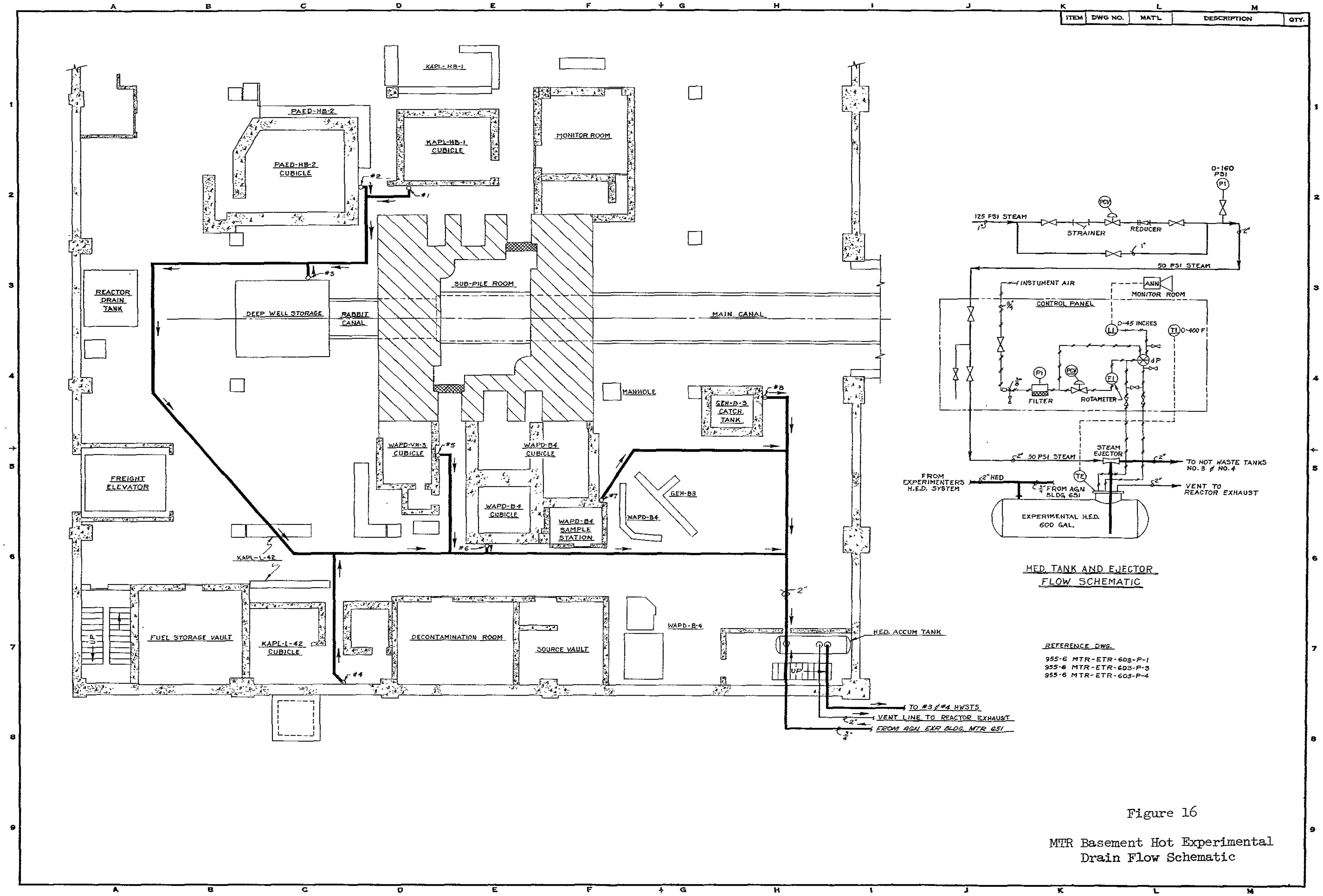
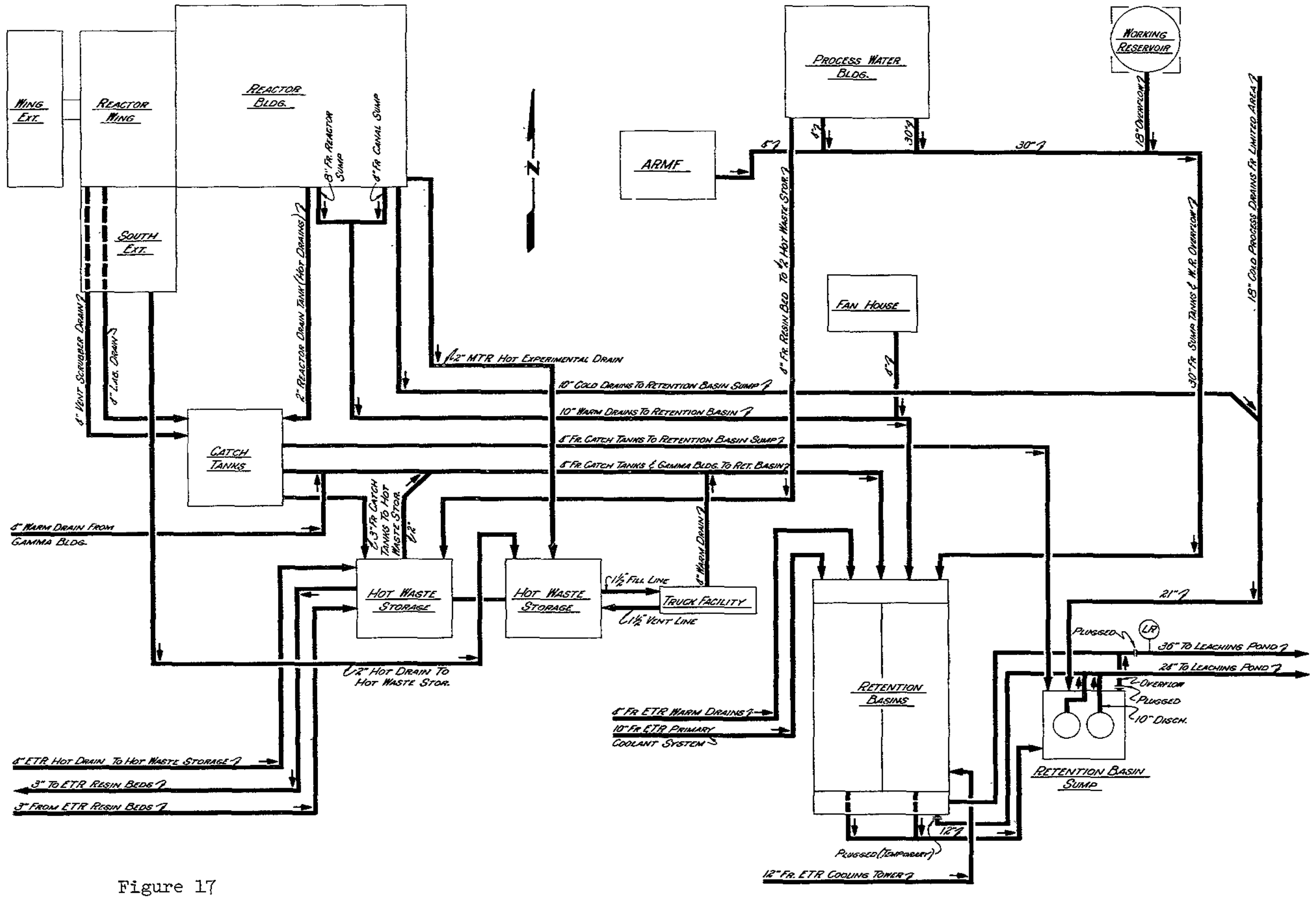


Figure 16

MTR Basement Hot Experimental Drain Flow Schematic



Reference Dwgs.
Koebig & Koebig-955-5-MTR-ETR-713-P-1—Hot Waste Storage Tk. Details
Koebig & Koebig-955-5-MTR-ETR-613-P-2—Hot Waste Stor. Flow Diagram
Koebig & Koebig-955-6-MTR-ETR-201-1—Hot Waste Lab. Drain & Yard Piping
Koebig & Koebig-955-5-MTR-ETR-642-E-1—Misc. Electrical Details
Kaiser-ETR-5528-MTR-642-P-7—ETR Yard Piping Misc. Details
Kaiser-ETR-5528-MTR-201-11—ETR Liquid Waste Disposal P&L Diagram
Phillips-MTR-E-4016—MTR-ETR Hot Waste Flow Diagram
Phillips-MTR-E-5303—MTR-ETR HED System

Figure 17

MTR-ETR Yard Piping
Contaminated Liquid Effluent

the MTR HP Shift Office. The HP on duty counts a one milliliter wet sample in the well counter and a dry 10 ml sample in the alpha counter. The results of these analyses are then used to determine whether the contents of the catch tank may be pumped directly to the retention basin or whether they must be put into the hot storage tanks. Present practice permits dumping to the retention basin where activity levels are less than 20,000 c/m/ml beta-gamma and less than 16 c/m/ml alpha.

b. MTR Hot Storage Tanks

Water sent to the hot storage tanks will normally contain high specific activity but short half-life fission products. It is only necessary to store it long enough to allow the specific activity to decrease to a level making it permissible to pump it to one of the retention basins. This is determined by periodic sample analysis while the water is in storage. Present dumping levels are less than 1000 c/m/ml beta-gamma and less than 1.6 c/m/ml alpha.

If analysis results indicate the effluent contains long half life beta or alpha emitters, the contents of the tank may be transferred to a tank truck and hauled to the Chemical Processing Plant (CPP).

c. Retention Basins (see Figure 17)

The retention basins represent the last places at which the effluent can be held up and possibly reduced in activity before being discharged to the leaching pond outside the fence. At nine foot intervals throughout the length of the tank, there are baffles to assure the longest possible time delay for the water passing through. This also encourages fine particulate or flocculent material to settle and remain at the bottom of the basin.

There are at present five inputs to the head end of the retention basins. These include waters from the catch tanks or hot storage tanks, ETR warm drains, ETR primary system drain, MTR canal sump and Reactor Building process sump, and the Process Water Building and working reservoir.

The retention basin overflow goes to the retention basin sump where two pumps are actuated by floats which pump this water to the leaching ponds. Cooling tower purge water is also drained into the retention basin dump adding its volume to the total which now flows directly out to the leaching pond outside the fence.

Water from all cold process drains throughout the area also dumps in here. Two pumps are provided to empty the sump intermittently into the leaching pond.

d. The MTR Effluent Water Monitor

The MTR effluent water monitor is located in a pit just south of the retention basins. It consists of a sampling system, a radiation monitoring system and a data integration and recording system.

The samplers are two minipumps. Each minipump operates in parallel with one of the retention basin sump pumps to deliver a proportional sample of the water discharged by it.

Both of the minipumps discharge to a common header. The water goes through a rotameter and a flask to a catch tank in the southwest corner of the pit.

The flask is mounted within a lead shield, and its contents are monitored for gamma radiation by a thallium activated NaI crystal and photomultiplier tube. The output of this detector is fed through an A1D preamplifier and amplifier to a linear ratemeter. The ratemeter output is fed to a recorder in the MTR Fan House.

Also mounted within the Fan House is the integrating circuit. The details of it need not be described here. It accepts data on flow rate of the two sump pumps and the data on activity from the radiation monitor. It then puts out a signal through a watt-hour meter, which is the product of the effluent water flow rate and the radiation count rate. The health physicist must determine its meaning by calibration of the flow rate measuring devices in terms of volume per unit time and by calibration of the radiation rate in curies per unit volume. Then the final readout can be made to represent an activity discharge rate in terms of curies per unit time. At present, the instrument has been calibrated so that 0.10 of the increase in watt hour meter reading per day equals the curie output, i.e., $Ci = 0.10 (Wh_2-Wh_1)$.

G. Supplemental Facilities at the MTR

In order for the MTR and ETR to operate, they must be supplied with facilities and services not directly involved in the nuclear reactions. Steam must be supplied to heat the buildings; water of various refinements must be supplied for a multitude of services including reactor cooling; air must be supplied for removal of reactor heat, to provide negative pressures in contaminated areas (cubicles, glove boxes, etc.); electricity must be supplied for light, power, and electronic devices. In addition to these facilities and services, there are also some small experimental and research groups that require MTR HP coverage. The following is a description of such services and facilities.

1. Service Facilities

a. Demineralizer Area

(1) Raw Water Production and Pumping Facilities

Raw water may be drawn from the subterranean water table (450-500 ft.) by any of three wells having a combined capacity of 8900 gpm. It is then stored in three 500,000 gallon, ground level storage tanks where pumps can draw from them for site usage. Some distribution pumps supply the 12 in. fire mains; others send water to the Demineralizer Building via an overhead storage tank. Still others supply the reactor cooling water evaporative losses. A supply of raw water is vital to the operation of the reactors.

(2) Demineralizer

Ion-exchange resin beds purify the water destined for canals, reactor cooling, and experimental usage. Raw water contains far too many foreign materials to permit its indiscriminate use in nuclear cores. The impurities would become radioactive and make work on the system unnecessarily difficult or impossible. Accordingly, both cations and anions are removed in separate resin beds so that water of purity approaching 1 part per million is produced. Maximum continuous production at 325 gpm is possible. For short periods, 400 gpm can be attained. With the addition of ATR, production capacity will be increased. Associated with this production facility are the necessary chemicals for regenerating the depleted beds and controlling the pH and conductivity of 200,000 gal. of stored demineralized water. Pumps send the water to the reactors and canals as necessary and to numerous experiments for both make-up and cooling. Temporary loss of demineralized water pressure could cause an MTR power reduction and prolonged loss would seriously affect operations.

(3) MTR Cooling Tower

Here the 40 million watts of heat generated in the reactor is dumped to the atmosphere. Since reactor water itself must not leave the "exclusion area," nor be exposed to contaminating windborn dust, it cannot be cycled directly through the cooling tower. Heat exchanges in the process building transfer reactor heat to the secondary cooling water which then circulates over spray baffles for evaporative cooling in a redwood tower. The water is treated with corrosion inhibitor which gives it an identifying yellowish cast. Loss or malfunction of the cooling tower and equipment would quickly necessitate an MTR shutdown. The cooling tower pump house, located west of the cooling tower, houses the secondary pumping system and controls for the large cooling fans.

These three areas are "clean" areas and no Anti-C clothing should be worn when doing maintenance work. The Demineralizer Building itself is smeared on a routine basis and a CAM is located in the building.

b. Steam Plant Area

Fuel oil (No. 6 Bunker oil) for the boilers and diesel oil for various engines and burners are stored in tanks at the northern edge of the site. A small pumphouse located there can transfer these fuels to the areas where their greatest usage occurs. Diesel oil, for the emergency power generators at the MTR and ETR and for the oil-fired air heaters at the ETR, is pumped automatically on demand by float-operated switches in the "day tanks" at the use locations.

Steam has its greatest use in the heating of buildings, although a considerable quantity is used in the MTR Process Water Building for drawing a vacuum in the flash evaporators. The steam is generated in three 17,500 lb/hr boilers which automatically adjust to the load and hold steam line pressure near 125 psig. If this pressure should fall to less than 100 psig, the drop in vacuum in the MTR process evaporators would result in rapid overheating of the reactor coolant; and this, in turn, would necessitate a reactor shutdown.

At present, air for the plant complex is supplied at 125 psig from a bank of four compressors located in a portion of the Steam Plant Building. All together, they can furnish 1100 cubic ft. per minute. The smaller compressor (200 cfm) can be driven by the emergency power generator in case of total failure of incoming voltage.

The air is eventually used in precision pneumatic instruments; therefore, it is passed through silica gel driers to reduce its dewpoint to 40°F below zero. From the storage tanks, the air system divides into two parts. One, the plant air line at 135 psig, goes to almost every building for what might be called industrial use: air motors, blowdown, etc. The second line is called instrument air and is the preferential system. If the compressors should fail and air pressure in the receivers drops to 115 psig, a control valve will close, reserving all remaining air in the system for the instrument line. This is done so that pneumatic instruments in the plant building, reactor control rooms, and experimental complexes will have signal air for proper indication and response during the initial part of an emergency period. Failure of the air system could quickly jeopardize the operation of both reactors due to instrument malfunction.

Also located in the compressor room at the steam plant is a 750 KVA, 2400 volt emergency generator driven by an 880 hp diesel engine. Associated with this automatic device is the necessary switchgear for distributing its power to locations in the MTR plant where emergency electricity is required during commercial outages. Lights in the buildings and along the fences are on this system; so are vital pumps such as fuel oil, condensate, and important water, elevators, and parts of experiments such as heaters, pumps, and some relay power. Since it takes the diesel about 15 sec. to come up to speed, power is interrupted to these loads for that time interval whenever commercial power fails. Commercial power failure for one second will scram the reactor.

These areas are considered the same as the demineralizer area with regards to health physics practices.

c. Hot Storage Facilities

The hot storage area is located north of the TRA. It is used for storage of contaminated and radioactive items that are used in conjunction with the reactors and experimental facilities. Contaminated articles that are stored outside of the building are boxed or covered with plastic. Usually pieces which are to be used again in the near future are stored unpackaged in the building.

The key to the area is kept at the TRA Main Gatehouse and is checked out by an HP when entrance to the area is requested. The HP should accompany the requestor to survey any items to be removed. A record of all items removed or placed in the area is kept in the MTR HP Field Office.

d. Hydraulic Facilities

A special facility for pressure testing fuel assemblies and shim rods is located in a building east of the main Reactor Building. Although only new fuel assemblies and shim rods are tested in this facility, there is a safety hazard as well as a potential low level contamination problem.

2. Experimental Facilities

a. Gamma Facility

The Gamma Facility is located south of the main gate at MTR. Here spent fuel assemblies from the reactors are used as gamma ray sources for commercial irradiations. It is considered a hot working area due to the handling of fuel assemblies in the canal. Everything that has been in the canal is checked even though the material is lowered into a fresh water column to be irradiated. A routine check is made of the area to make certain that no contamination is spread around. A CAM is located in the facility and a radiation detection head is directly over the north canal parapet. This is not a security area.

b. Cold Metallurgical Lab

The Cold Metallurgical Lab is the first building to the left after entering the main gate. This facility is designed to fabricate fuel pieces of uranium and thorium using different metals and then to study their cross-sections after they have been irradiated in a reactor core. Two of the greatest hazards involved in the fuel fabrication are the spread of alpha contamination and the spread of beryllium dust.

A new addition to the Cold Metallurgical Lab now under construction will house a group operating an electron microscope and probe studying burn-up characteristics of fuels. Irradiated samples will be made from fuel sections prepared in the Hot Cell. Such small cross-sections will be used that the samples will read as low as 1 R/hr.

c. ETRC

In the east corner of the MTR Service Wing is the ETR critical facility. This facility is a small swimming pool type reactor studying flux measurements at different core configurations. Tracerlab monitoring instruments located in the building alarm in the HP office when radiation limits are exceeded. A CAM is located in the building and operates independent of the MTR system. HP coverage is necessary whenever any "hot" pieces are removed from the reactor pool in this building.

d. ARMF

The Advanced Reactivity Measurement Facility is located in Building 660 east of the MTR Reactor Building. It operates two small reactors in a common pool. Since all reactivity measurements are made at a low power level, contamination is generally very low level. The Tracerlab radiation monitoring system is tied into this building with an alarm and print-out in the HP office. The CAM is not tied into the MTR system but operates separately. Any "hot" material removed from the pool must be monitored by an HP.

3. Fuel and Experiment Handling Facilities

a. Hot Cell

The Hot Cell Building is located south of the MTR Reactor Building. It consists of three heavily shielded cells, two of which can be divided into two individual sections. An area north of the cells is used for office space and working area for the manipulation of the remote handling devices for handling of materials inside the cells. Access to the cells is gained through heavily shielded doors on the south side. Adequate tool and storage area is provided on that side. Large doors are provided to allow trucks to transport casks to and from the access area. An overhead crane is also included. A change room is located between cells 1 and 2.

The purpose of the hot cells is to determine how the irradiated materials in the test reactors are affected by intense neutron and gamma irradiation. This is accomplished by performing standard engineering tests on samples of the materials. For protection to personnel during the tests, the cell walls are concrete, four feet thick with leaded glass viewing windows the same thickness in the front working areas. A separate air system inside the cells provides enough suction to prevent light particles or gaseous activity from escaping to the rest of the building.

The samples are kept in shielded containers until they are actually in the cells and are generally removed in the same container. In some cases, this is done by unloading or reloading the casks within the cell. In others there are ports in the cell walls through which the samples must be pushed to or from a specially designed cask to make the transfer.

When in use, the cells are locked, and hot cell supervision must authorize entrance with an HP escort. At completion of a test, the material is remotely loaded back into the cask; hot waste material not reloaded is placed in a trash cask. The working area is then vacuumed with the aid of remote manipulators using a vacuum cleaner located inside the cell.

The initial entry into the cell should be approached with caution since air contamination and high radiation fields can be encountered. A CAM sniffer hose should be used to check the air when the doors are first opened and then be placed at the opening during entry. Anti-C clothing should be worn in the area immediately behind the cell. The area inside the cell is highly contaminated, and protective breathing equipment, latex and cloth shoe covers, and full protective clothing are required.

Finally, the clean-up of the cell should be carefully handled to prevent the spread of contamination outside the ribboned areas and to prevent any untagged contaminated or high radiation sources from leaving the ribboned area. If a hazard exists at the close of a shift, it should be properly tagged and supervision should be made aware of it. A careful check should be made by the HP at the start of a shift.

A standard procedure for all Hot Cell personnel is set down in the directive "M-E-ATR Hot Cell Exposure and Contamination Control Procedure" KRH-51-63A-M. This directive can be obtained from the HP foreman and should be reviewed by HPs before monitoring in this area.

4. MTR Chemistry Laboratories and Counting Rooms

At the MTR there are two sets of chemical laboratories. The sets differ according to the kinds of radioactivities predominating in each.

a. Labs 109-112

Laboratories 109 through 112 are devoted to such things as the necessary radiochemical analyses of the primary coolant systems and experimental loops in both reactors. The predominating radioactivities handled in these laboratories are fission and corrosion product beta activities.

All of these radioactivities are contained in bottles or capsules until it is time for the chemistry to be performed on sources to be prepared. Much of the work with them is done on open benches which are protected with blotting paper. Any operations, such as the evaporation of aqueous samples, which may give off fumes are done in fume hoods. The hoods are swept by air entering the front and exhausted through a high efficiency filter in the MTR Hood Exhaust System.

b. Alpha Wing

In a new south extension to the MTR Wing are laboratory facilities designed for the safe handling of hazardous alpha emitters. Such radioisotopes as U-233, Pu-239, Am-241, and other transuranic elements are routinely handled there.

The radioisotopes arrive in sealed vessels packed in cans at the point of origin (usually ORNL). These cans are usually opened in one of the fume hoods, and the inner container is placed in a clean beaker. The beaker containing the sealed radioisotope is then placed in an appropriate dry box where the container may finally be unsealed.

The dry boxes are of two general types. For handling small quantities of radioisotopes which do not emit very much gamma radiation, glove boxes are provided. The chemist may perform most of his operations manually through glove ports in the face of the box. For handling radioisotopes emitting gamma radiations in large quantities, a large cave facility is provided into which two dry boxes may be inserted. The handling must then be done with the use of mechanical manipulators.

These boxes are each connected through a high efficiency filter to the MTR Vent Scrubber System. The pressure within the system is about 2 inches of mercury lower than atmospheric. Thus, minor openings in the dry boxes have air flowing into them from the laboratory. A differential pressure monitoring system has been installed with alarm signals in each laboratory which are actuated if the vacuum goes below 1 inch of mercury. The alarms consist of red lights and buzzers.

Most of the chemical processing involving these alpha emitters is performed within the boxes; but materials such as waste, dirty glassware, and end-product samples must be removed intermittently. Clean containers are introduced through an air lock on the end of the box. Materials to be removed are placed in them and then removed through the air lock.

There are occasions when the chemists remove samples of low specific activity either to the open bench or to a fume hood. Containment is breached only when the consequences of a spill are considered small.

The wing is provided with health physics radiation monitors, an alpha hand and foot counter, a beta-gamma hand and foot counter, a beta-gamma portal monitor, and alpha-beta CAMs. The laboratories are surveyed routinely for beta and alpha contamination. Both smear and survey meter checks should be made in any area which could be alpha contaminated. These smears should be counted immediately for alpha radioactivity. Survey instruments to be used are a hand-carried instrument for checking bench, hood, and dry box exterior surfaces and a carriage mounted instrument used for monitoring the floor. Special health physics surveillance services are provided upon request.

c. Counting Rooms

Room #125 located in the Reactor Building West Wing is a counting room containing various counting instruments used by trained personnel to determine specific activity and half life of various samples. Since some of these samples are hazardous, HPs should carefully check this area on routine contamination checks and hazardous area checks. The HP should be familiar with the instruments and their operation, especially the 512 channel crystal spectrometer and the thyroid counter used in connection with the spectrometer. A second counting room is located in the MTR wing basement. It is used for flux monitoring and other special counting purposes.

5. Personnel Facilities

These areas are normally considered cold areas where no Anti-C clothing is allowed, and frequent close checks are necessary to maintain them as such.

a. Gate House

The Gate House and front gate are entrances into the area through which all personnel and vehicles must pass. All personnel not driving vehicles must pass through friskers when they enter or leave the area; and if any contamination is suspected, they are held until health physics determines the nature and extent of the contamination. All materials not of a personal nature are checked and must have a health physics green tag signifying approval for removal before they can be removed. Security works closely with health physics in enforcing this procedure. Personnel metering equipment and identification badges are also issued here. Emergency equipment is stored at the Gate House for use if and when the Test Reactor Area (TRA) must be evacuated.

b. Dispensary

The TRA Dispensary is located approximately 200 ft. northeast of the area Gate House. An area contractor (Idaho Nuclear Corporation) employed nurse is on duty during the regular week days. Whenever a nurse is on duty, all injuries and requests for medical assistance should be referred to her. This is maintained as a clean area, and special decontamination equipment and facilities are located here in case of an emergency.

c. Cafeteria

This building is located north of the main Reactor Building and provides services for the TRA. A frisker is maintained at the entrance to check personnel as they enter. Special care should be taken during routine contamination checks to insure that this area remains a cold area. Whenever personnel are entering the cafeteria and the frisker alarms, any HP in the building has the responsibility of checking the cause of the alarm and making certain a contaminated individual is sent to the HP office for decontamination before eating.

6. Other Facilities

a. Fuel Storage

Two locations are used at MTR for storage of fuel assmeblies and shim rods containing fuel. They are the storage cage in the reactor wing basement and fuel vault in the southwest corner of the reactor basement. There should be no more than 2 fuel racks out of the vault at one time. If 2 are out, they should be placed 10 feet apart. Cadmium-lined shelves are used for the storage racks; and, if proper procedures are followed, the storage is in a safe configuration. Flooding the fuel vault could possibly cause a criticality; therefore, no water should be used in fighting a fire in either storage area.

b. X-Ray Cubicle

A special cubicle for radiography has been built in the southeast corner of the south reactor wing. A check must be made after each radiograph before entry can be made into the cubicle. Health physics should work closely with the personnel operating this equipment to insure that no unnecessary exposures occur. Cobalt-60 and Iridium-192 sources and one X-ray instrument are used by this group.

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CHAPTER III

ENGINEERING TEST REACTOR

A. Engineering Description of the Engineering Test Reactor

1. Philosophy and Design Summary

The Engineering Test Reactor (ETR) was designed and constructed to perform engineering tests of fuel elements and components of nuclear plants. In order that these tests be made under conditions simulating the actual proposed application certain requirements had to be met. These are as follows: (1) the reactor would have to generate very high thermal and fast flux in the core holes, (2) provision had to be made in the core (high flux zone) for test facilities ranging in size from 3 in. x 3 in. x 36 in. to 9 in. x 9 in. x 36 in., (3) a reasonably uniform flux from top to bottom of the core had to be maintained, and (4) the reactor would be designed to contain closed-loop type facilities for circulating any coolant fluid.

The above conditions led to a reactor design quite different from that of the Materials Testing Reactor (MTR). The foremost differences are: (1) all experimental facilities in the ETR are vertical and are placed inside the reactor vessel, and (2) the reactor control rod drives are mounted below the reactor bottom head where they are least affected by the experimental facilities. (See Figure 18.) The latter is dependent on the first, since the designers foresaw that the upper vessel area would be too congested with experimental facility tubes, hangers, etc., to permit the use of control drives extending downward from the top head.

The vessel top was established near floor level because of the large clear height needed to remove experimental trains and facility tubes. The depth of the vessel, position of the core, size of the biological shield, etc., were governed by allowable radiation levels and biological considerations.

The building size was determined by the number of experimental facilities and the instrumentation and equipment spaces required for each.

2. Description of Reactor

a. General

The ETR Facility is a complete nuclear engineering test facility located south of and adjacent to the MTR. As such, it includes its own compressor building, heat exchanger or process water building, electrical building, and office building. The above are independently functioning buildings built with common dividing walls.

b. Reactor and Components

The reactor is light-water cooled and moderated and has a thermal rating of 175 MW. It is housed in a 3 floor-level gastight building.

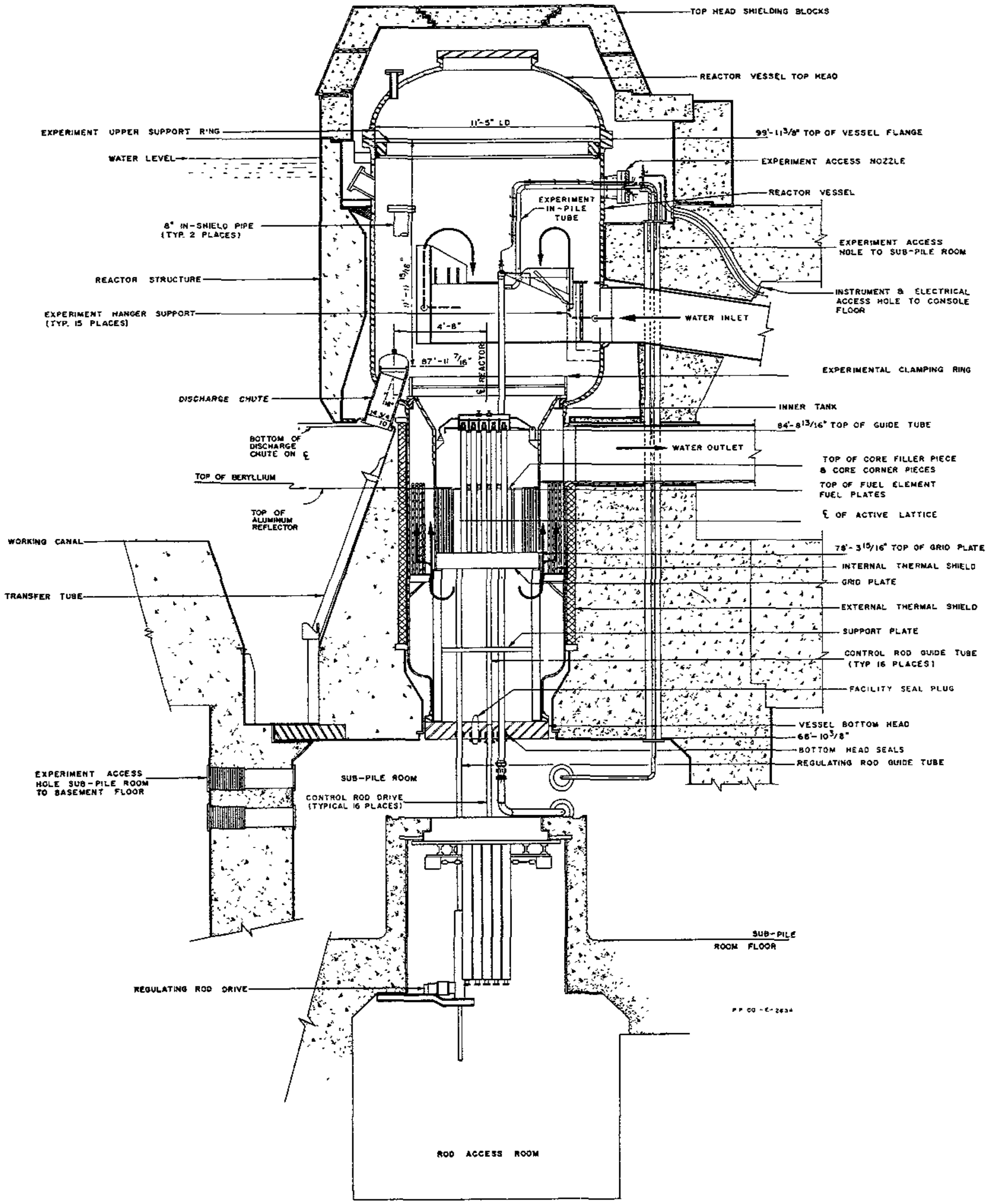

Figure 18

ETR Structure Vertical Cross Section

The reactor vessel consists of a multidiameter vessel, a removable elliptical dome with flat top flange, a flat bottom head, a discharge chute, an inlet water flow distributor, experimental hanger supports, experimental access nozzles, and the process water inlet and outlet line connections.

The internal parts of the vessel are the inner tank, the internal thermal shields, the reactor core, the core support structure, and the experiment upper support ring (see Figure 19).

The reactor core consists of a 30.4 in. x 30.4 in. square array of 52 fuel elements, 12 shim control rods, 4 safety control rods, 4 corner filler pieces, and 9 experimental facilities (see Figure 20).

The fuel elements are an assembly of aluminum clad, enriched fuel, plates. The plates run vertically the length of the assembly and are spaced far enough apart to allow the proper coolant flow.

The control rods are similar to the fuel elements but consist of two sections, a fuel section and a poison section.

The inside reflector is a 4-1/2 in. thick layer of beryllium extending completely around the core.

Aluminum reflector pieces extend from the beryllium reflector out to the inner tank walls.

The core filler piece is a solid piece of aluminum penetrated vertically by twenty-eight 1/4 in. cooling holes. It is used for replacing fuel elements in the core during shutdown.

The experimental holders (4-x pieces) are approximately the same dimensions as the fuel elements or the aluminum reflector pieces and have 4 experimental holes running vertically. These pieces are used within the core or reflector to receive the aluminum experimental baskets (x-baskets), which actually contain the slug and capsule type experiments.

The reactor vessel is enclosed and supported by a high density concrete biological shield extending from the first floor to the basement ceiling. The 25 ft. outside diameter of the shield is covered with a 3/4 in. steel plate.

3. Reactor Building

a. Reactor Building Main Floor

The reactor building is 136 ft. in the east-west direction and 112 ft. in the north-south direction. It extends 58 ft. above the grade and 38 ft. below grade to the basement floor.

The high bay area above the first floor has a clear height of 47 ft. to the bottom of the roof truss structure. The first floor is at the same floor elevation as the MTR main floor. The first floor is designed for three intensities of loading. That part of the first floor between column centerlines E 24 - E 25

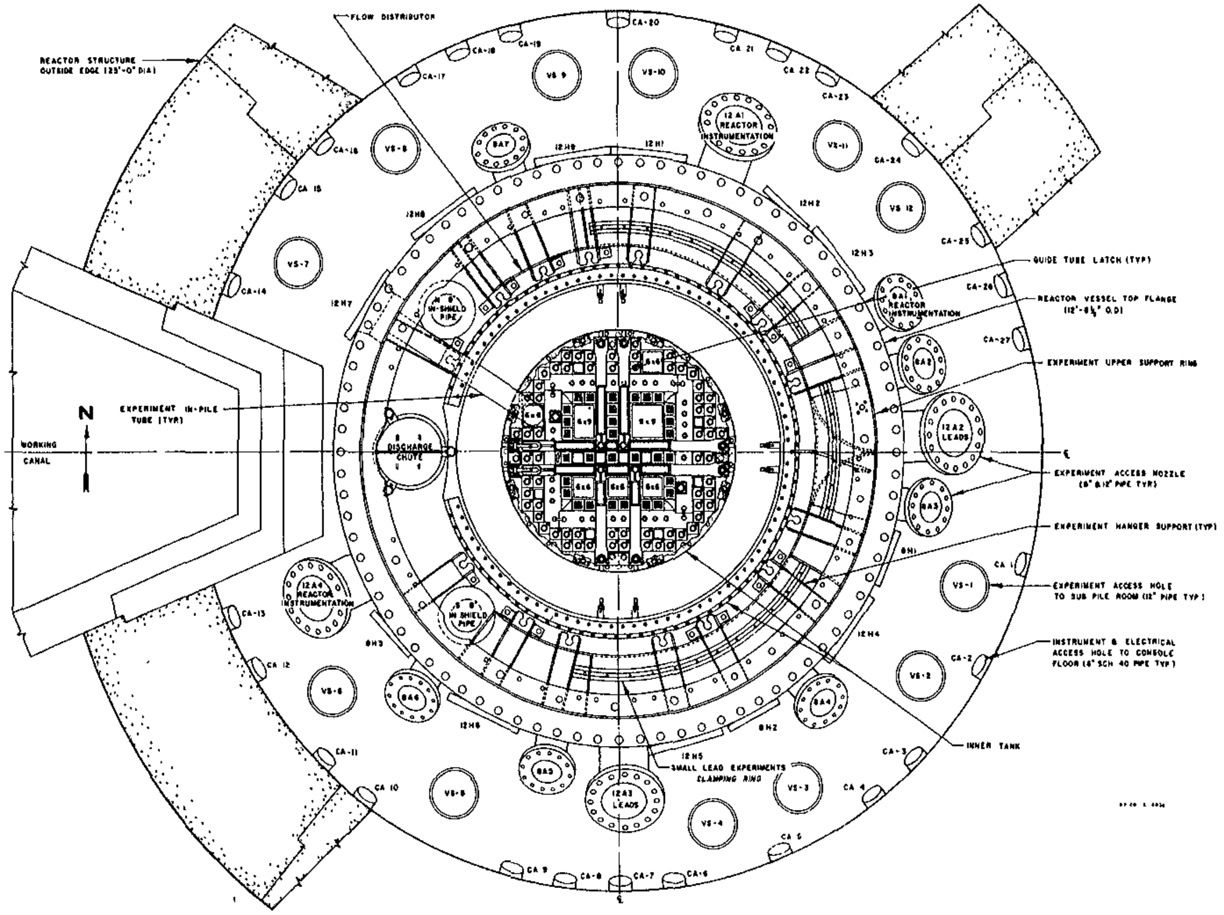

Figure 19

ETR Structure Top Plan
With Vessel Head Removed

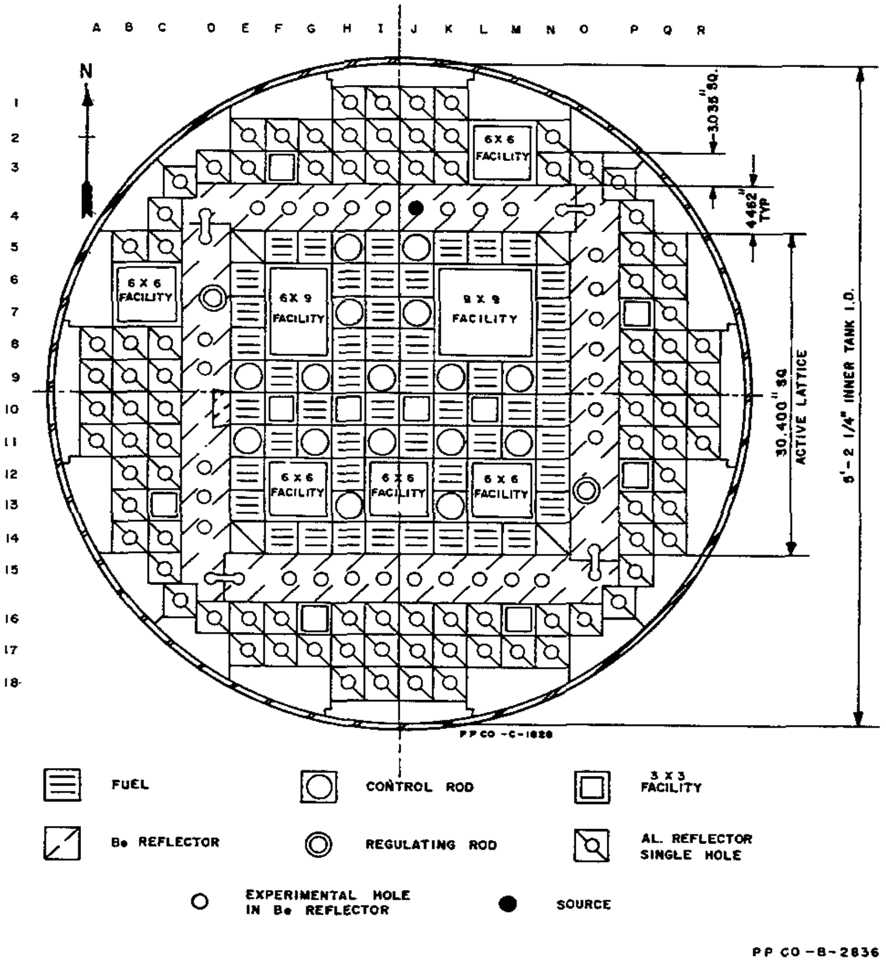

Figure 20

ETR Lattice and Reflector
Horizontal Cross Section Above Core

from the north truck door to and including the pipe tunnel, the eastward extension of the pipe tunnel, and the remaining floor area north to the edge of the stair well enclosure is rated at 1000 psf. The central floor area in the vicinity of the reactor is limited to 750 psf. This area extends 22 ft. south, 29 ft. 2 in. west, 27 ft. north, and 27 ft. 6 in. east of the reactor centerline (except where this area overlaps the 1000 psf area described above). The balance of the first floor area is limited to 350 psf. The bounds of these floor areas are painted on the floor for quick reference. The first floor slabs are 10 in. thick except for the 1000 psf area where it is 12 in. thick.

The working canal extends westward from the reactor structure, and the process water pipe tunnel extends eastward from the reactor structure under the first floor.

b. Console Floor

The console floor, approximately 22 ft. below the main floor, serves the dual purpose of a shielding roof for experimental cubicles at basement level and a working level for experimental consoles and equipment. The walls of the pipe tunnel, the biological shield, and the canal walls extending from the first floor to the console floor divide the console area into halves connected only at the west end by a 9 ft. 6 in. wide corridor. The entire console floor is rated at 350 psf. The part of the floor directly over the basement cubicle area is constructed of 3 ft. thick ordinary concrete; the balance of the floor is 1 ft. thick.

A 30 ft. x 80 ft. balcony has been added on the south side of the console area in order to obtain additional floor space for experimental instrumentation and control equipment. The balcony is designed for a load of 200 psf.

c. Reactor Basement

The basement floor is approximately 38 ft. below the main floor. It rests on a compact fill and is designed for a 900 psf load.

d. Intra-Building Access

Personnel access between floors is by means of two circular stairways located north and south of the working canal, an enclosed stairwell in the southeast corner of the reactor building, a stairwell and passenger elevator in the northeast corner of the reactor building, a stairwell from the south console floor to the first floor level in the electrical building, and a stairway from the north console floor to the main floor level of the office building.

Equipment access between floors is by a 10 ft. x 14 ft., 10-ton capacity freight elevator located near the north truck door in the northeast corner of the reactor building or by two hatchways north and southeast from the reactor centerline.

e. Sub-Pile Room

The area directly under the reactor is known as the sub-pile room. It is separated from the basement area by a 4 ft. thick high density concrete circular wall. This room is 20 ft. in diameter. The floor elevation is the same as the basement floor. The walls of the sub-pile room act as shielding, and also as a support for the reactor and biological shield. Access is by means of a shielding door opening to the basement on the east side.

The sub-pile room is the area in which experimental in-pile tubes connect with experimental piping, and this piping is routed to the experimental cubicles via access holes in the wall. Fission and corrosion products sometimes lodge within this piping and within the rod drives and can cause extremely high radiation fields. Any work within the sub-pile room must be accomplished during reactor shutdown and be done under Health Physics surveillance. While the reactor is operating, the door is kept locked.

f. Control Rod Access Room

The control rod access room is located directly below the sub-pile room. This room is reached by a stairway extending westward from the basement floor level. As the name implies, it houses and provides access to the control rod, regulating rod, and control chamber drive mechanisms.

Entry into the rod access room during reactor operation or the first access allowed at the start of shutdown operation requires a Health Physics survey to ascertain that no hazards exist from beams being emitted from the core through the bottom shielding plug. These radiation fields can be very directional (collimated) and careful surveys must be made so that high intensity beams with small diameters are not overlooked. Continuous Health Physics surveillance is also required during control rod removal operations during reactor shutdowns. The upper ends of the rod drive mechanism are usually highly contaminated. Care should be exercised in removing these mechanisms from the rod access room to avoid overexposure to men and to prevent dropping "hot" particles while carrying them up the stairs. A high level radiation monitor is located in this area but is useful only in detecting scattered radiation or radiation from rod removal operations.

B. Brief Description of an ETR Cycle

A reactor cycle has been designated as a six-week period consisting of approximately two weeks of shutdown with the balance of time devoted to maintaining the reactor at 175 MW. The shutdown times are fixed and the dates distributed to interested parties which allows them to coordinate their experimental scheduling properly. Due to the multitude of experiments, the varied experimental operating parameters, and individual experimenters' requests, a reactor cycle may be extended or shortened. A cycle begins with a reactor shutdown.

A shutdown period is a time of great potential radiation hazard. During shutdown, repairs and alterations are made to experimental and plant facilities. Shutdown work may consist of over 100 work orders. The majority of these work orders will require a special work permit and health physics monitoring. Each work order must be scheduled, and each system or item of equipment must be in a safe condition before any work is done. For this reason, all work requests and special work permits must be carefully considered and signed by the Operations Shift Supervisor prior to the commencement of work.

When the shutdown work is completed, the reactor dome is bolted in place, the primary system is filled and pressurized, and normal flow is started. Startup check sheets are completed on the primary coolant system, the reactor control system, and all associated facilities.

A reactor startup is usually an orderly process, but offers certain dangers due to the lack of sensitivity of instruments at extremely low power levels. The four black safety control rods are withdrawn first, then the grey rods are withdrawn according to a prescribed rod program. The rod withdrawal program is designed to prevent flux peaking in the reactor core and possible experiment over-heating. At each step in power, all experiments must be checked for any off-normal points and for any potential dangers. Full power must be approached cautiously to prevent any high experiment sample temperatures. Also, at high power levels the secondary coolant system cannot absorb rapid temperature changes.

The optimum power run would be to reach full power four to six hours after startup and maintain full power until the core is depleted or until the end of the cycle. There are a great many things that can cause reactor "down time," so an optimum run seldom occurs. Experimental and plant failures such as heat exchanger leaks, thermocouple failure, instrument failure, and breakdowns of plant equipment can occur. Operational mistakes such as closing an incorrect breaker or switch, opening or closing the wrong valves, or failing to recognize a malfunction before it causes trouble can also cause reactor "down time". Each equipment failure or operational mistake requires an upgrade in that particular piece of equipment, a change in operational procedure, or an addition to personnel training to prevent a similar occurrence.

A nuclear test reactor designed to test nuclear fuel samples at extreme conditions presents certain perils not associated with a plant of more conventional objectives. Certain calculated risks must be accepted to conduct a full experimental program. However, all risks must be minimized and backups provided to prevent incidents. Test reactors provide a small margin for error, and a minor situation can rapidly deteriorate and cause an incident; therefore, an operating philosophy must be developed in which safety of personnel and plant is of paramount importance. Incidents, reactor shutdowns, and serious equipment failures can be minimized and often prevented by a well-trained, alert operating force. Vibrations, off noises, and any unknown situation should be immediately investigated and reported to the responsible persons.

The over-all objectives of test reactor operation are somewhat mixed. A large yearly MW-day record is some measure of operating efficiency, but this could easily be reached with capsule irradiations and no irradiation in engineered loops. To utilize the experimental facilities fully, a working program level has been established in which all effort is directed toward a maximum power output consistent with safe operating practice and total sponsor requirements.

C. Reactor Tank Operations

1. Introduction

Shutdown work in the reactor tank is generally performed by Operations personnel. Tank work consists of refueling of the core and shim rods, discharge and insertion of experimental capsules, leads, pieces, and the transfer of items within the reactor. Considerable damage to the reactor and experiments could result from placing an experiment or piece in the wrong position, so each item is carefully identified and its location recorded by Operations personnel.

An HP is required to be on the reactor top (or in the immediate vicinity) anytime anyone is working there. His responsibility is to monitor the radiation fields and air activity levels and insure that safe procedures are followed. The HP should take care of his own duties and leave the tank work to Operations and Maintenance.

2. Safety in Tank Operations

a. Bottom Head Penetration Work

During penetration work on the bottom head for insertion and removal of experimental tubes and shim and regulating rod drives, extreme care must be taken to prevent loss of reactor water. Wheneven bottom head penetration work is being done, the discharge chute cover should be off to provide an additional reservoir of water. In the event a major leak should occur in the bottom head, immediate steps should be taken to keep water over the reactor core. This can be done by adding demineralized water into the primary system, or fire water with a fire hose, or through the emergency fire line into the primary water system.

b. Handling of Radioactive Materials

When radioactive materials are being transferred to the canal, moved within the reactor, or removed from the reactor in any way, there should be constant Health Physics monitoring. All items coming out of the reactor are highly contaminated and should be stored in the canal underwater or wrapped in polyethylene. Care should be taken while discharging fuel elements or other irradiated material to the canal to see that they are lifted only high enough to clear the discharge chute. When a job is to be done that could result in exposure to personnel, it should be thoroughly planned and monitored.

c. Reactivity Consideration

Whenever any work is done in the reactor that could cause an increase in reactivity, the count rate meter should be diligently observed. There is a slave count rate meter for use at the reactor top. This should be on and the alarm setpoint set or the count rate meters in the control room watched. Shim rods should be replaced before the rest of the fuel elements. Only one rod should be changed out at a time.

d. Entry into the Reactor Tank

Whenever there is a reason for a man to enter the reactor tank to do shutdown work, there must be an HP present at all times. The man will be required to wear protective equipment, such as two pair of Anti-C coveralls, a full-face or air supplying respirator, cap, gloves, boots, and eye protection. For further protection, a safety line attached securely to the man is required.

e. Operations Surveillance of Work in the Reactor

Any work done in or over the reactor tank must be with attendance of the responsible Operations personnel designated by the Shift Supervisor. This insures that the proper procedures are followed to prevent damage to the reactor and associated equipment and also that the workers obey Safety and Health Physics rules. Proper precautions, such as taping down film badges and other loose objects, should be taken against dropping items into the reactor tank. If by chance something is dropped into the tank, it should be reported immediately to Operations and retrieved promptly.

3. Preparing the Reactor for Shutdown Work

a. Degassing and Flushing

Immediately after reactor shutdown, the system is degassed for a period of two hours. This minimizes the release of radioactive gases when the reactor dome is removed. Following this two hour period of degassing, the reactor is flushed with fresh demineralized water at a rate of 1500 gpm for a total flush of 60,000 gallons. This operation reduces the level of radioactivity in the process water.

b. Shielding Removal

Removal of the concrete biological shielding rings surrounding the reactor top is necessary to gain access to the reactor top dome. This is done with the overhead 30-ton crane.

c. Lowering of the Tank Water Level

The water in the reactor vessel must be lowered below the top vessel flange before the top dome is removed. A 4-in. upper drain line is provided for this purpose. A plug valve in this line is operated by an extension handle at the northwest corner of the reactor shielding. While lowering the tank level, air must be vented into the reactor from a vent valve on the top head. Attention should be given to the warm sump tank level indicator to prevent overflowing.*

d. Contamination Control

During shutdown the open reactor tank is an ever present source of contamination. Fission and corrosion products present in the tank water settle and plate out onto the metal surfaces of the tank, the experiments, the handling tools, and other equipment. As these items are exposed to the atmosphere, the radioactive materials have a tendency to oxidize and flake off and be carried and spread by the air currents and on the clothing and bodies of careless personnel. Hence, prior to the removal of the dome, necessary contamination control measures should be taken.

The areas to the north and south of the reactor are usually ribboned off and designated as hot working and hot storage areas, respectively. The highly trafficked portion of the floor space of these areas is completely covered with blotting paper and a containment apron of plastic is run along the ribbon to help minimize the spread of radioactivity.

e. Top Dome Removal

An HP must be present whenever the top is removed to insure adequate personnel protection.

In order to remove the reactor top head, it must first be unbolted from the reactor tank; and any experimental piping penetrating the top dome must be stripped and the gland seal packing loosened. The cap is removed from one of the top head penetration holes to accommodate the small "dragon." With the dragon hooked up and exhausting the dome, the dome is lifted with the 30-ton crane to a height of about 3 inches and held in this position for approximately 10 minutes. This is usually sufficient time for any radioactive gases which might have been trapped to be swept from the dome and expelled to the cubicle exhaust.

This dome is then lifted slowly, and if no sharp increase in air activity is noted**, the dragon is disconnected and the dome is

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* When lowering water level in the reactor or while purging the canal, if caution is not used, it is possible to exceed the capacity of the sump pumps. If the sump tank high level annunciator goes unheeded, water backs up into the drain lines flooding the rod access room with contaminated water accompanied by high level air activity. Water will also back up into the cubicle exhaust line. This stops the air flow and allows air activity to be emitted from all open drain lines such as the canal drains on the main floor. If the water backs up high enough, it will be siphoned into the basement cubicle exhaust header and then leak out onto the basement floor from the open butterfly valves.

** To prevent the contamination of the ventilating system in the event there is a release of air activity, it is very worthwhile to open the truck door, turn off the supply fan, and close the recirculation damper before removing the dome.

stored south of the working canal. The refueling platform is then placed over the reactor and the large dragon connected to the adapter of the platform. With the dragon drawing air down through the "keyhole" and into the cubicle exhaust, any radioactive gases or particulates coming from the inner surfaces of the reactor, the experiments or the reactor water will be carried away to the stack. Thus, only a minimum of radioactivity will be allowed to escape into the atmosphere of the reactor building.

This minimum of radioactivity which escapes, however, contains enough radioactive iodine for the first few hours to necessitate the wearing of an organic respirator by those who are working directly over the reactor tank.

f. Discharge Chute Cover

Before removing the discharge chute cover, the water level in the reactor tank and in the canal must be equal. When the reactor tank level is at the upper drain and the canal level at the overflow height, the level will be correct. The discharge chute hold-down lugs are then loosened and the highly contaminated cover is removed from the reactor with the 2-ton crane, using a large hook tool, and stored on the shielding under a cover to prevent the spread of contamination.

4. Tank Operations

a. Control Rod Change-Out

As a precaution to prevent the possibility of a criticality, the control rods (poison) are always changed before the standard core fuel assemblies are changed out; and only one control rod is removed from the core at any one time. If more than one rod must be removed at the same time, the surrounding fuel elements must first be removed.

To remove the control rod, the control rod drive must be raised a few inches to release the coupling balls from the shock tube.

To remove the poison section, the handling tool is lowered into the top of the guide tube until the square cross section of the tool matches up with the upper adapter of the poison section. The lugs of the tool are then engaged in the cut-outs in the poison section, and the entire assembly is raised until the poison section clears the top of the guide tube. Then by rotating clock-wise, the latching springs of the poison section are disengaged allowing the fuel section and the shock section to fall back into the guide tube.

The control fuel section is removed in the same manner as the poison section. The shock section can also then be removed from the guide tube.

b. Guide Tube Removal

There are two common methods of removing the guide tubes. If their path is not obstructed by experimental piping, they can be discharged through the discharge chute into the canal. Because of the length of the guide tube (15 ft.) the canal pit cover and the transfer tube assembly must be removed to allow the guide tube to be lowered sufficiently to clear the bottom of the discharge chute.

Before the canal pit cover is removed, the sub-pile room should be evacuated and the door locked. This will eliminate the possibility of someone being in the sub-pile room and receiving a dangerously high radiation exposure. The 8-1/2 in. steel plate which serves both as the floor of the canal pit and the roof of the sub-pile room would hardly provide sufficient shielding if a fuel element reading approximately 10^7 R/hr were accidently dropped into the pit.

Due to the increase of experimental piping in the reactor tank, the removal of some of the guide tubes through the reactor to the discharge chute is impossible. Consequently they must be lifted by means of the 2-1/2 ton crane and a block and tackle up and over the top of the reactor and the working platform and lowered into the canal.

The section of the guide tube which has been in the active lattice will always be highly radioactive. The activity level will depend on how long it has been in the core, and how soon after shutdown it is removed.

It is possible for the irradiated section of these guide tubes to read in excess of 1000 R/hr at contact. For this reason it is desirable to perform the removal on an off shift. With problems such as this, it is always wise to discuss carefully the details beforehand with both Operations and Health Physics supervision and then proceed with caution using the principles of distance, shielding, and time to keep the exposures of personnel involved to a minimum.

To replace the shock section, the control rod drive must again be raised a few inches. The shock section can then be lowered into position. It must be oriented with its spring latches in the east-west direction.

To insert the control rod fuel element, it is latched to the handling tool and lowered into position, orienting the fuel plates in the east-west direction.

The poison section is inserted in the same manner with the spring latches in the east-west direction.

The latching of the rod is then checked by running the control rod down to its lower limit. This resets the balls and couples the drive to the shock section. If the rod is properly latched, it cannot be lifted with a tool.

c. Removal of Control Rod Drive

In order to perform maintenance work on a control rod drive, it must be removed from the bottom head, and generally, from the rod access room.

As a preliminary step in the removal of a control rod drive, the control rod and the guide tube must be removed. After removal of the control rod, the drive should be lowered to its lower limit so nothing protrudes above the bottom head. The hole in the bottom head above the rod drive is then plugged, using the Kaiser M-889 plugging tool. The electrical connections to the rod drive are then removed, the motor uncoupled, and the seat switch removed. The shock section of the drive is then unbolted from the bottom head and the drive removed carefully checking for excessive water leakage.

Health physics surveillance is required during rod drive removal operations. Not only is there danger from collimated beams from the reactor core through the bottom shielding plug, but also the bottom ends of these rod drive mechanisms are usually highly contaminated. Care should be exercised in removing these mechanisms from the rod access room to avoid over-exposure to personnel and to prevent dropping "hot" particles while carrying them up the stairs. A high level monitron is located in this area but is useless in detecting the collimated beams.

After the rod drive has been replaced, the plugging tool is removed by tilting the head vertically and going through the guide tube penetrations diagonally. The tool is lifted with the rope tackle rather than the crane to prevent tool or core damage.

d. Fuel Element and Filler Piece Changes

A C-hook is used to transfer the depleted fuel elements and the filler pieces to the discharge chute. Care must be taken to insure that the fuel element is not raised any higher than necessary, thus reducing the shielding afforded by the water.

New fuel elements are brought from the MTR fuel storage vault in specially constructed racks (12 elements per rack). To prevent a criticality these racks will be located such that a minimum of five feet of clear space remains on all sides of the rack. Also, not more than two fuel elements shall be removed from the rack to the reactor refueling platform at any one time.

The fuel element plates are oriented east and west while in the core. The core filler piece bail must be placed east and west in the core.

e. Reflector and Experimental Piece Changes

The aluminum reflector and experimental pieces are provided with a knobbed lifting pin. The pieces are lifted and transferred in the same manner as fuel elements. The experimental 4-X pieces have one top corner milled down. This is usually oriented to the northeast.

f. Lead Experiment Insertion

A lead experiment is generally a capsule-type experiment with instrumentation leads for connection outside the reactor. These leads are encased in an aluminum or stainless steel tube that is attached to the capsule and which extend out through the access nozzles at the top of the reactor tank section.

The lead tubes are made in two sections joined by an in-tank connector. The upper and lower sections are positioned in the reactor and then the in-tank connector is made up. After the experiment is in position, it is clamped to the tank wall with remotely operated clamps. A special flange is then placed over the lead tube and is sealed at the nozzle against loss of reactor water. The lead connections are then made up and the experiment pressure-tested.

g. Insertion of Experimental Tubes

There are 15 bottom head penetrations provided for experimental in-pile tubes. There will be specific insertion procedures for each experiment that is installed, but the general procedures for insertion will be similar. As a safety precaution to prevent a criticality, four fuel elements must be removed from the core before any experimental changes are made. Also, there should never be more than one in-pile tube removed at a time. For the insertion of some tubes, it may be necessary to remove pieces and control rods adjoining the facility.

A hydraulic jack is placed under the bottom head seal plug and the seal plug retaining ring removed. A seal plug adapter piece is attached to the lower end of the experimental tube to mate with the top of the seal plug. The experimental tube is then carefully lowered into the reactor vessel, through the grid plate and the support plate, until the adapter piece is mated with the seal plug. With constant communication between the reactor top and the sub-pile room, the seal plug is then jacked up slightly to be sure the plug and the adapter are together. While the seal plug and the experimental tube are being lowered, frequent stops are made to insure that the tube and the seal plug are still in contact. This is continued until the experimental tube is through the bottom head.

The in-pile tube is then positioned and attached to supports inside the reactor tank. The piping in the sub-pile room and the reactor tank may now be welded to the in-pile tube.

5. Preparing Reactor Tank for Startup

a. Tank Inventory and Inspection

When the reactor shutdown work is completed, an inventory is taken by Operations of all reactor positions containing experiments. The purpose of this is to check the shutdown work to make sure that all experiments are in their correct position and that no capsules have been lost or misplaced. The vertical positioning of the experiments is verified with the inventory tool. It is lowered onto the basket or hole and the inner plunger rod is lowered until it comes in contact with the capsules. The reading is then taken, recorded, and checked against master loading sheets.

The tank is then visually inspected for any foreign matter, tools or parts of tools that may have been dropped into the tank, and to see that all positions are full, and that all pieces and experiments are properly seated. Any irregularities are corrected.

b. Guide Tube Support Arms

The guide tube support arms are now lowered into place. The long arms are lowered first, insuring that the latching pin on the west end of the arms has latched. The short arms are then lowered onto the long arms and latched into place.

c. Discharge Chute Cover

The discharge chute cover is now put in position. Before lowering into the tank the "O" rings are checked and the latching dogs are extended to eliminate binding on the discharge chute. The cover is then lowered carefully onto the discharge chute and is latched in place.

d. Dragon

The dragon is removed and stored and the damper in the cubicle exhaust vent is turned to exhaust air from the nozzle trench area.

e. Top Dome

Before the top dome is replaced, the refueling platform is removed and the reactor "O" ring is replaced. The dome is then lowered taking care that the experimental tubes are not damaged and that the dome is centered properly before setting it on the reactor. The top dome is then bolted down.

f. Fill and Leak Check

When the top is bolted down and the experimental tube packings are made up, the tank is ready to be filled. The upper reactor drain line is closed and a hose with a quick disconnect fitting is placed on the vent valve of the top dome and bled to the canal. The reactor tank is then filled with demineralized water through the primary water system until water is obtained from the vent line. The vent is then closed and the reactor pressured to 180 lbs. The top dome seal and all packing and flange seals are checked for water leaks.

g. Shielding

Before the reactor can go to power, the concrete biological shielding rings must be replaced around the reactor top. After this is done, thermocouples and pressure leads to experiments penetrating the top dome are connected and tested.

6. *HP Check List for Reactor Top Work*

The following is an HP check list guide for reactor top work: (1) obtain portable instrument of adequate range and check its calibration; (2) on the off shift check and, if necessary, replenish the supply of shoe covers, gloves, glasses, face respirators, etc.; (3) have Amyl acetate on hand to check respirator face fit; (4) make sure that radiation monitrons are functioning properly; (5) check to see that the dragon is connected and the damper lever properly set so that air is being exhausted from the reactor tank; and (6) make certain that both CAMs are working and that their "sniffers" are taking representative samples of the working area atmosphere.

D. The ETR Canal

1. Description of Canal

The canal is T-shaped and consists of two sections, the working canal which is 37 ft. long and 8 ft. wide, which connects with the reactor vessel, and the 60 ft. long and 12 ft. wide storage section. Except for the pit underneath the reactor discharge chute, the water depth is 20 ft. throughout, which gives a 1 ft. freeboard. The canal floor is rated at 200 psf plus the water load. The working canal can be isolated from the storage section by the insertion of a bulkhead at the junction. Also a portion of the working canal near the reactor can be isolated by means of a second bulkhead. This facilitates draining for the repairing of various sections of the canal.

a. The Working Canal

(1) Use and Equipment Location

The working canal provides sufficient working room for the removal of experiments from the reactor tank to the canal. In order to remove experimental equipment of lengths up to 15-1/2 ft., a pit is located in the canal floor below the normal position of the unloading mechanism. Fuel elements and experimental sections are transferred from the reactor into the working canal through the discharge chute in the reactor vessel transition piece. This is accomplished by lowering the fuel element into a transfer tube located in the canal under the discharge chute. The transfer tube, which is hydraulically operated, is pivoted to permit an operator to secure the element by a hook tool from the canal. (See Figure 18.) The operator then "walks" the element to the storage racks. Fuel elements have a tendency to float when transferred through the water with any speed, which presents an additional radiation hazard.

The canal working platform is permanently attached to the east end of the canal parapet and permits access to the working area of the canal immediately over the reactor transfer tube. The platform is constructed in two sections on either side of the canal with an open working area in between the sections. Each section is served with a stairway from the first floor level.

An underwater saw is located on the south wall of the working canal to cut off fuel element end-boxes and to cut in-pile piping into disposable lengths. Also by the south canal wall is a capsule reloading tray, flux wire storage grid, and a Kollmorgan underwater periscope used for capsule inspection.

Along the bottom of the canal are the S and T grids, each made up of a 9 in. x 7 in. grid of 4 in. aluminum piping for storage of capsule experiments and several trash cans for storage of low level radioactive scraps for later removal to the burial grounds.

(2) Fissionable Material Control

To prevent the inadvertent assembling of a critical array of fissionable material during canal operations, the following will be observed.

(a) Fissionable material on the capsule tray or periscope tray is limited to 300 grams.

(b) Baskets containing fissionable material will be stored in rows 1 and 7 only of the S and T grids.

(c) The concentration of fissionable materials in the S and T grids will be no more than 100 grams per foot per position.

b. Storage Canal

(1) Location and Use of Equipment

The storage canal has additional storage space for irradiated fuel slugs, experimental equipment, fuel elements, and reactor core components. The north half of the storage canal has been designated for storage of non-fissionable core components in the P and R grids and storage of fuel assemblies in cadmium-lined storage grids A, B, C, D, E, F, G, and X, Y, Z. The X, Y, and Z grids are short grids for the storage of cut fuel elements and control elements. Numbered and lettered stainless steel buckets have been provided for irradiated capsule storage. Spent fuel elements are stored in the 36-hole, cadmium-lined storage grids to "cool" before being cut and shipped to either the Gamma Facility or the Chemical Processing Plant. The south half of the canal storage area is used for storing long in-pile loop experimental samples and other bulky items such as the ORNL-505 Water Column.

(2) Fissionable Material Control

Specially constructed cadmium-lined storage grids are provided for safe storage of spent fuel. They are designed to prevent the inadvertent assembling of a critical array of fuel during canal operations. Under no circumstances are fuel elements to be stored outside the storage grids except as follows: if all grids are full, the excess fuel elements may be lined up end to end in a single row along both the west and east walls of the storage canal.

Other safety precautions regarding fissionable materials are as follows: (a) fissionable material stored in buckets is limited to 300 grams per bucket; (b) at least 1 foot clearance must be maintained between loaded buckets and other fissionable material; and (c) 1 foot clearance must be maintained around each in-pile loop sample.

2. ORNL - 505 Water Column

This column is located in the southeast corner of the storage canal. It utilizes depleted fuel elements as a source for gamma irradiating various materials for experimental purposes. The following safety restrictions must be observed:

(1) No fuel element is to be loaded in the circular center hole of the 12 element array.

(2) At least a six inch spacing must be maintained between the periphery of the array and any other extraneous fuel assemblies being stored or moved within the canal.

(3) Only MTR and ETR fuel elements are to be used, and they should not exceed 480 grams of U-235 per element.

3. Shipping

All irradiated capsules, experiments, and depleted fuel elements are transferred from the canal in shielded containers. The experimenters provide their own casks to ship capsules and experiments. The casks are lifted with the 30-ton crane, lowered into the canal, and loaded with the experiment. After loading, the cask is raised out of the water under HP surveillance*, wiped dry, and checked for direct radiation and contamination.

Standard fuel assemblies and control assemblies discharged from the reactor are usually stored from one to four months in the canal prior to shipment to the Chemical Processing Plant.

Standard fuel assemblies are shipped to the Gamma Facility a day or two after being discharged from the reactor. Due to the excessive heat generated by these elements, the assemblies are shipped a few at a time.

4. Transfer Cask

The fuel element transfer cask is designed for use as a shield in transporting cut fuel elements from the ETR Reactor Building to the MTR Gamma Building or the Chemical Processing Plant. Up to eight fuel elements may be moved at one time, depending on the cool-period out of the reactor. The inside dimensions are 15 in. in diameter by 40 in. high. The lead thickness is approximately 11 inches. The outside diameter is 38 in., and the over-all height is 5 ft. 10-3/4 inches. The weight of this cask is approximately 24,800 pounds. The bottom end of the cask is rectangular with shoulders on two opposite sides to fit the straddle carriers. The lead is encased inside and out with stainless clad carbon steel or solid stainless steel plate. At the lower end, the inside shape is changed to an 11 in. square clear area to conform to the shape of the transfer basket. In the transfer operation, the fuel elements

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* Health physics surveillance is necessary whenever any object is removed from the canal whether it is in a cask or not.

are lowered into the cask and are placed in the transfer basket which acts as a support or divider. The transfer basket is removable and resembles the fuel storage racks in many respects, including the cadmium lining around all eight positions.

5. Canal Piping

The canal is supplied with demineralized water from the MTR storage tanks. For "quick-fill," a 4 in. stainless steel pipe is used with the water entering the working canal north wall at 12-ft. water level. For canal purging, a 3 in. stainless steel pipe is provided. The purge is supplied at two locations in the storage canal and two locations in the working canal. The rate of purge is controlled by a manual valve at each location, adjustable from 0-100 gpm per valve and operated from the first floor along the canal parapet wall. Normally, the purge system will operate at a fraction of its capacity which will be sufficient to keep the activity in the canal to a permissible level under normal operating conditions. The rate of purge is determined by the rate of activity from spent fuel elements and experiments and is sufficient to maintain the canal water temperature below 90°F.

The original adjustable overflows with 3-in. pipe connections were found to be useless and were removed, and fixed level overflows were installed. Each overflow has a capacity of about 120 gpm, and drains into a 6 in. canal drain terminating in the 5000 gal. "warm" sump tank. In addition to the overflow, there are three drain sumps containing 6 in. valves in the canal floor; one is located in the storage canal and one within each bulkhead compartment in the working canal.

One danger everyone should be aware of is the possibility of flooding the basement. If the canal purge is left on and all power to the building is off or if the warm sump pumps malfunction, water will back up the warm sump tank vent system into the rod access room.

6. Canal Shielding

The planned 20 ft. water depth of the canal will allow 15-1/2 ft. of water above the active section of fuel elements stored in the canal and will reduce the radiation above the canal to 1/35 tolerance if 65 fuel elements were placed in the canal 2.5 hrs. after shutdown.

There would be about 3 ft. of water between a group of 65 spent elements and the canal wall if a single row of storage racks were placed midway between the canal walls. In order to reduce the radial gamma radiation to 1/10 tolerance, the lower sections of the canal wall are 6 ft. of ordinary concrete. The upper section is tapered to about 2 feet.

In the region of spent element storage, the walls are 7 ft. thick. Space limitations make it necessary to place storage racks of irradiated fuel elements against the canal walls. The fuel elements in the canal will have 1-1/2 ft. of water below the active sections. This water, in addition to the 7 ft. of ordinary concrete in the canal floor, will attenuate gamma radiation to 1/30 tolerance below the canal floor.

The region between the pressure vessel and the canal water contains sufficient shielding material to attenuate radiation from the core to tolerance levels in regions around the top of the canal. The only real danger of radiation would come from dropping a "hot" source into the canal pit. The 8-1/2 in. of steel separating the bottom of the canal pit from the sub-pile room would reduce the intensity of 0.7 MeV gamma field by a factor of about 10^5. So if a fuel element reading approximately 10^7 R/hr at one foot was accidently dropped into the canal pit, the resulting radiation field in the sub-pile room would be approximately 100 R/hr.

To eliminate this obvious hazard, a steel cover plate is normally kept over the canal pit. If for any reason this cover plate must be removed, the sub-pile room should first be evacuated of any personnel and the door locked to preclude the possibility of a serious incident.

7. Radiation Monitoring

a. HP Surveillance

Anytime any radioactive material is raised in or removed from the canal, whether in a cask or not, it should be done under health physics surveillance.

b. Monitrons

Monitrons located on the Reactor Building west wall, at the south end of the storage canal, at the south circular stairwell, and in the sub-pile room serve as a warning in the event there is a rise in the radiation level around the canal area.

c. Water Samples

Once each week, 100 ml samples are taken at 3 overflow points in the canal and delivered to Health Physics for determination of beta-gamma activity.

E. ETR Cooling Systems

1. General Description

The heat removal system of the reactor consists of a primary cooling system which absorbs the reactor fission heat and rejects it to a secondary cooling system, which in turn dumps the heat to the atmosphere through cooling towers. Light water is the coolant used in both systems; the primary coolant in the reactor is also the moderator. The primary loop consists of demineralized water which is exposed to the atmosphere only in the degassing tank. The secondary cooling system is in contact with the atmosphere at the cooling towers. These two systems are separated by the tubes in the primary heat exchangers, which are designed to prevent leakage between the primary and secondary cooling systems. Activity in the primary and secondary cooling water is continuously monitored.

2. Primary Cooling System

a. Major Functions of Components

(1) Flow (See Figure 21)

The primary system supplies approximately 50,000 gpm of light demineralized water to the reactor vessel. This water passes through the reactor core at a velocity of approximately 32 ft. per sec. and removes the heat that is generated in the reactor core. The main flow loop is a closed circulating loop which consists of the following components.

Four large centrifugal pumps are used to circulate the water. These pumps are located in the pump pits.

Each pump discharges approximately 15,000 gpm of water into a 24 in. line. These lines run to a common 36 in. inlet header which carries the water to the reactor vessel. The water leaves the reactor vessel through a common 36 in. outlet header. These headers are located in the primary pipe tunnel. The outlet header carries the water to the heat exchangers.

Just upstream of the heat exchangers, the water splits into four individual systems again. In each system, a 24 in. line carries the water through a heat exchanger bank and to the suction of a primary pump. Thus, the loop is completed. There is a motor operated block valve, called a limitorque valve, located on the suction and discharge side of each primary pump. These eight valves are operated in the full open position during normal operation of the primary system. There is also a check valve located on the discharge side of each primary pump.

The flow to the reactor vessel is measured by a Gentile tube located in the reactor inlet header (see Figure 22). It primarily measures the flow that actually passes through the reactor vessel. The flow that goes to the reactor is controlled by two valves. The first is a motor-operated butterfly valve that is used as a throttling valve. Throttling the butterfly valve decreases the flow delivered by the primary pumps. The second valve is a control valve located in a 10 in. line that connects between the inlet and outlet headers. The valve is called the bypass valve since any flow passing through this valve bypasses the reactor vessel and the Gentile tube. A differential pressure controller monitors the pressure drop across the reactor core and automatically positions the bypass valve to maintain the desired differential pressure across the reactor core. Since the 10 in. bypass valve is relatively small, the butterfly valve is used to make a coarse setting on the flow to the reactor vessel. In this way, it is possible to keep the bypass valve within its control range at all times.

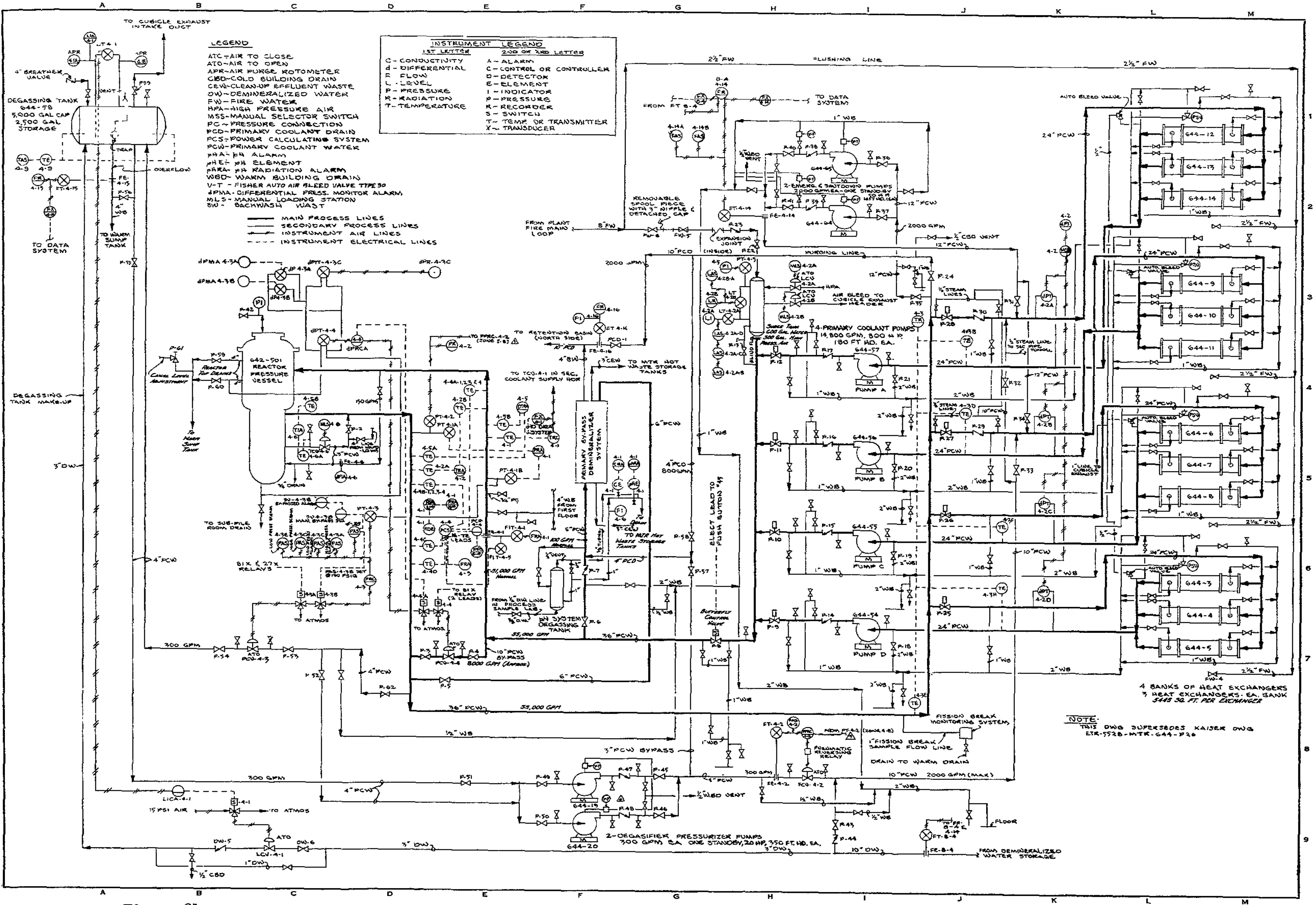

Figure 21

ETR Primary Coolant System
Piping and Instrument Flow
Diagram

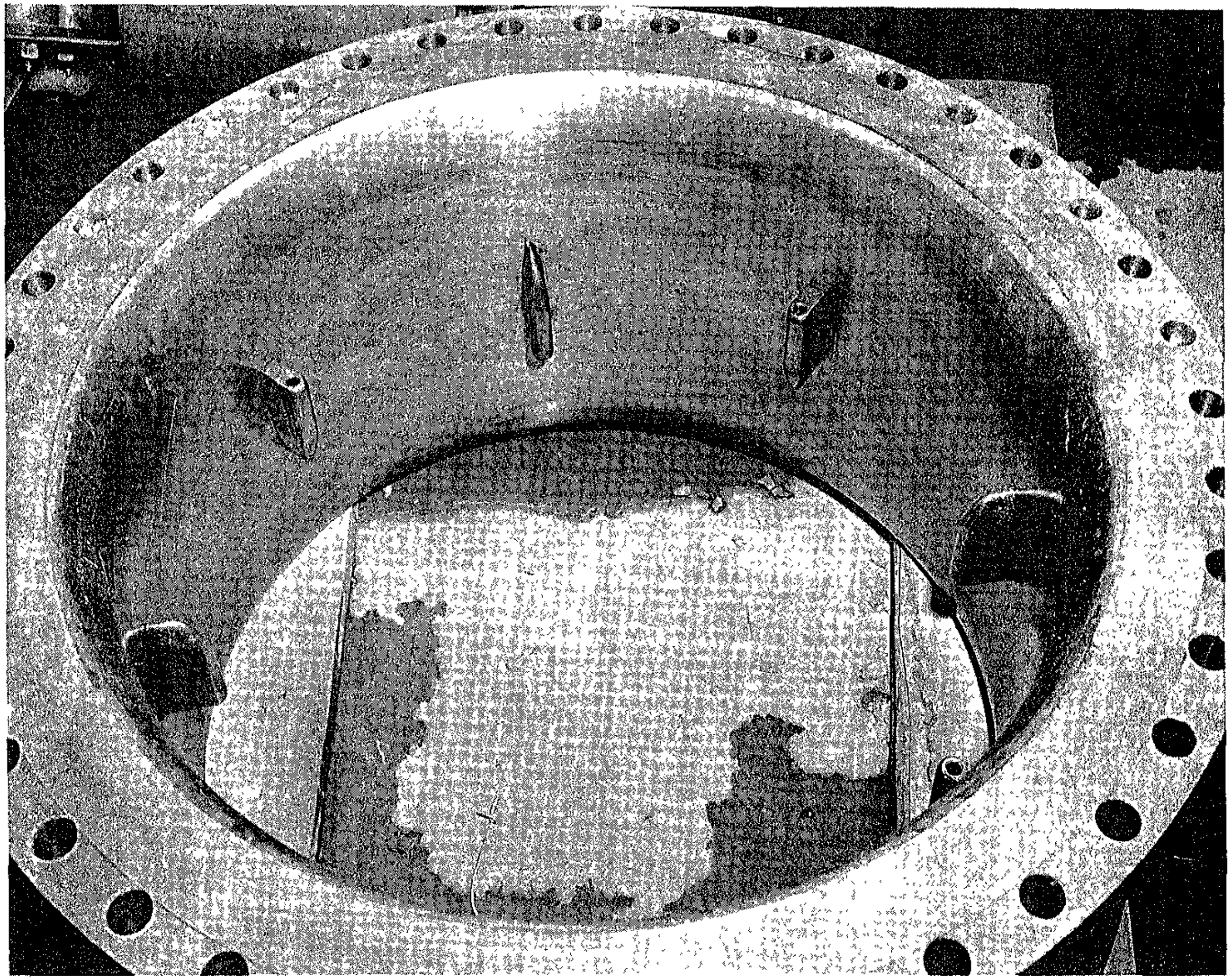

Figure 22

ETR Gentile Flow Tube

(a) Pump Pits

The primary water pumps are located in concrete pits at the south end of the compressor building.

All pump pits should be monitored for air activity when the hatch covers are removed. The pumps are usually highly contaminated inside and should be monitored whenever work is to be done on them.

(b) Primary Pipe Tunnel

Access is allowed in the primary pipe tunnel only during reactor shutdown periods. The first entry at the start of shutdown requires determination of the presence of any air activity and a careful survey by Health Physics to locate radiation sources. Air activity is a problem here while the reactor is operating and immediately after shutdown. High radiation fields may be found due to radioactive sources accumulated in the bottom of the pipes and at welds and valves in the lines. Continuous monitoring is required as long as reactor primary water flow continues. Anti-C clothing including latex foot wear must be worn at all times.

(2) Pressure

The pressurizing requirements of the primary system are based upon a temperature of 110°F and a pressure of 200 psig at the discharge of the primary coolant pumps. The system pressure is controlled by adding a constant amount of water from the degassing tank to the primary system by means of a pressurizing pump, and removing a varying amount of water from the primary system to the degassing tank through a back pressure control valve.

The degassing tank is equipped with an overflow line and a demineralized water makeup line containing a level control valve. Thus, the level in the degassing tank remains nearly constant even though the amount of water entering and leaving the tank is not necessarily constant.

(3) Temperature

The primary water system is designed to operate at a reactor inlet temperature of 110°F under normal reactor conditions of 175 MW and 50,000 gpm flow and an outlet temperature from the reactor of 135°F. The primary system transfers the reactor head to a secondary water system through the heat exchangers.

The reactor inlet water temperature is controlled by varying the rate of heat transfer to the secondary system. This is accomplished by varying the flow rate and temperature of the secondary water system.

(4) Heat Exchanger

Located in the heat exchanger building are twelve shell-and-tube heat exchangers. There are four banks of three heat exchangers, each in parallel, each bank being stacked in a vertical plane. The exchangers use a shell-and-tube counter-flow arrangement with primary water flowing through the tubes. The units have fixed double tube sheets and are of a straight through, one pass design (see Figure 23).

Entry is restricted into the Heat Exchanger Building at all times due to high radiation fields from radioactive deposits in the heat exchangers. This is especially true during reactor operation when the radiation fields are greater due to fresh activity and when high level air activity is also prevalent. Air activity is a problem only when the reactor is up or within a few hours after shutdown. The air activity level can easily be determined by attaching a CAM sniffer hose to the stand pipe located just east of the Compressor Building sample room door. This stand pipe opens into the Heat Exchanger Building.

All entries require an HP in attendance. Anti-C clothing including latex foot wear and proper respiratory equipment is required.

(5) Degassing

A 5000 gallon degassing tank is located on the roof of the Heat Exchanger Building to remove dissolved gases. Primary coolant water flows through the tank at atmospheric pressure at a maximum flow of 300 gpm. Fission gases are removed, and an explosive mixture of hydrogen and oxygen is prevented by passing air, at atmospheric pressure, over the water surface of the tank and venting the mixture to the cubicle exhaust system.

The original calculations made on H_2 and O_2 gas production indicate that the equilibrium between production and recombination will be reached at a gas concentration much lower than the minimum value necessary to cause bubble formation in any part of the system. It was predicted that the equilibrium gas concentration under actual operating conditions would be approximately 5 cc/liter. Actual measurements found the gas concentration to be 40-50 cc/liter, which is still well below minimum solubility of 166 cc/liter at the primary pump inlet.

The quantity of gas that can be removed by this equipment is directly proportional to the gas concentration in the primary cooling water. At the predicted concentration, approximately 0.2 scfm would be removed. In addition to removing water decomposition products, the degassing device will also perform the following functions: (a) remove hydrogen resulting from corrosion of fuel elements and structural material; (b) remove carbon dioxide formed by oxidation of any trace of organic material in the system; and (c) remove the noble fission gases, such as krypton and xenon, which will result from a fission break.

Because of the lower pressure, the solubility of gases will be lower in the degassing tank than anywhere else in the system. Hence, the possibility of gas bubble formation in the core or any other part of the primary loop is eliminated.

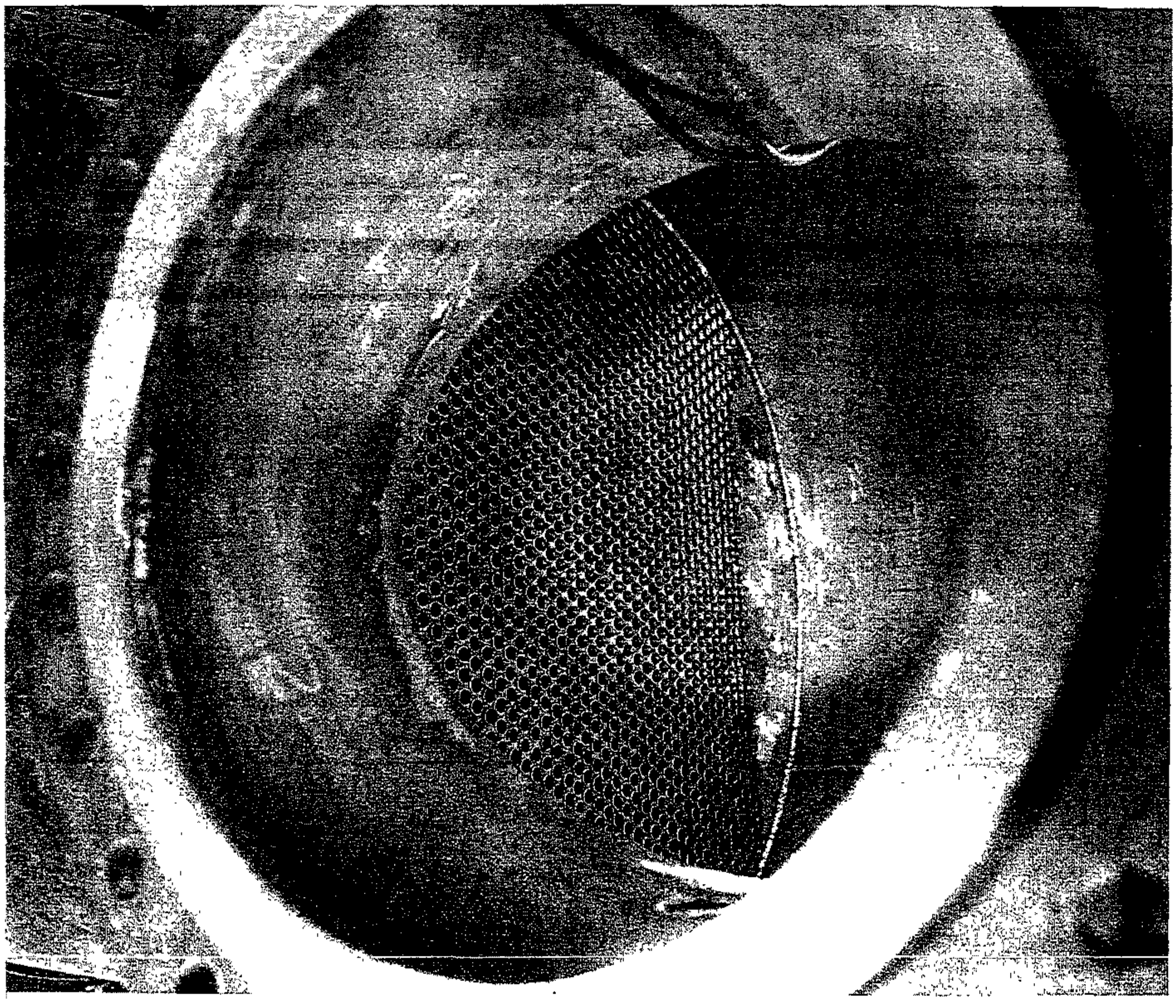

Figure 23

ETR Primary Heat Exchanger
Showing End of Tube Bundle

(6) Bypass Demineralizer

In order to maintain the required high purity of the primary water, a bypass demineralizer system consisting of two anion beds and two cation beds has been installed.

It will limit the ionic impurities in the primary water to 1/2 ppm corresponding to 1,000,000 ohm-cm by demineralizing a bypass flow of 100 gpm. It is also capable of short term operation at 300 gpm for fission product removal and for reducing radioactivity prior to dome removal.

The system was designed for non-regenerative operation, but has been modified to provide for the regeneration of the anion beds. Spent resin which is highly radioactive is slurried into a disposable casket. The fresh supply of resin is fed into the tanks with demineralized water. This water is drained to the warm sump tank or the retention basin.

The system is designed for flexibility so that each tank may be completely or partially bypassed. The pH is controlled by bypassing part of the fluid around the anion or cation tanks.

A connection is provided at the inlet to the tanks for pumping hot waste from the MTR hot waste tank through the demineralizer system before it goes to the retention basin. This may be done at the rate of 100 gpm.

(a) The Ion Exchange Cubicles

The ion exchange beds are located in these cubicles.

Only very limited access is allowed due to the extreme radiation fields and confined nature of the area. Such access is probably permissible only after regeneration and then would require a meticulous survey by Health Physics.

(b) ETR Demineralizer Valve Room

This room houses the piping and valves, etc. of the demineralizer system. Air activity is always a hazard, especially during reactor operations since there is no exhaust system. Air activity can be monitored by attaching a CAM sniffer hose to the stand pipe which is located just east of the Compressor Building sample room door.

All entries require a health physics survey to determine radiation fields and locate localized sources in the process water piping. An area radiation monitoring head is located in the demineralizer valve room with a read-out located in the process water control room.

(7) Emergency Flow

Several emergency situations may arise that involve the loss of normal flow in the primary system. In these cases, the reactor is automatically shut down. It is necessary, however, to maintain some flow through the reactor core to remove fission product decay heat, and thus prevent nucleate boiling in the core. This essential flow is supplied by the "Emergency and Shutdown Pumps".

The two primary emergency pumps receive their power from the disel generator bus. One of the pumps runs continuously during reactor operation. The standby pump is set to start immediately upon failure of the running pump. Approximately 2000 gpm of primary water is supplied to the suction side of the emergency pumps from the 36-in. reactor outlet header just upstream of the heat exchangers. The emergency pumps then return this water to the primary system at two points. The water can re-enter the main loop on the inlet line to either the "A" or "B" banks of the heat exchangers. Normally, it enters at both places.. There are check valves on the inlet lines to "A" and "B" heat exchanger banks which are located between the points where the emergency flow leaves and re-enters the main loop. These check valves close on loss of main flow. Thus, the flow from the emergency pumps must circulate through the reactor vessel in order to return to the suction side of the emergency pumps.

(8) Activity Monitoring and Sampling

(a) Constant Radiation Monitors

Three radiation systems continually monitor the water in the primary system; two N-16 measuring systems and one fission break monitoring system.

Some of the O-16 in the primary cooling water is converted to N-16 by the absorption of a neutron as the water passes through the reactor core.

$$O^{16} + n \longrightarrow N^{16} + p \qquad (8)$$

The amount of N-16 formed is a function of the neutron flux in the reactor. N-16 has a half life of 7 sec. and emits a hard gamma ray as it decays.

$$N^{16} \longrightarrow O^{16} + \beta^{-} + \gamma \qquad (9)$$

The intensity of the gamma radiation on the primary system is measured by a scintillation detector located at the outlet header just downstream of the reactor. The amount of gamma radiation is proportional to the amount of N-16 and, this, to the neutron flux. The readout of this instrument is located in the reactor control room, and, under normal conditions, it is used to indicate reactor power level. But since the detector is relatively non-selective and is not only sensitive to the N-16 decay gamma ray but to the gamma rays emitted by fission products as well, a fission break will be indicated almost immediately by a rapid rise on the N-16 recorder.

A more certain but less timely indication of a fission break is given by the "fission break monitor." It was designed specifically to detect fuel element failure by the presence of fission products in the primary cooling water. Water is drawn continuously from the primary outlet header. The sample passes through a pressure regulator, a flow meter, and a glass wool filter. The sample then passes through a cation exchange column for the absorption of all major radioactive corrosion materials. This leaves only the materials normally associated with a fuel element leakage, viz, iodine and bromine. Iodine-135 and others are concentrated in the anion column. This column is continuously monitored by a gamma scintillation detector. The intensity of the gamma radiation is proportional to the iodine in the primary water and indicates the presence and severity of a fission break.

This instrument which is located on the north console floor is calibrated by HP C-shift personnel twice each week.

(b) Water Samples

Each day samples are taken of the primary water and from each operating resin bed and delivered to health physics for a determination of gross beta-gamma and alpha activity. The results are recorded and reported to the process operator. Any abnormal results are given to the shift supervisor. Other samples may be requested at any time.

(9) Primary System Surge Tank

The primary surge tank has a capacity of 900 gallons. The tank is connected to the primary system by an 8-in. line with a block valve. The block valve is open during normal operation of the primary system. The tank is normally half full of water. The remaining half of the surge tank is occupied by air compressed to the primary system pressure at the discharge side of the primary pumps. The level in the tank is controlled by bleeding high pressure air in or out of the tank through valves controlled from a remote manual loading station.

The air cushion in the surge tank serves to smooth out any pressure surges in the system. Also, at times when the reactor power decreases rapidly, the temperature of the primary water decreases rapidly. This, in turn, reduces the volume of water in the main primary loop. The water in the surge tank, with the compressed air as a driving force, serves to fill the void volume in the primary system and keep the main loop liquid full.

b. Reactor Vessel Considerations

(1) Tank Level Controls

The reactor top dome is in place, and the reactor vessel is liquid full at all times during normal operation of the primary system. During periods of shutdown, however, the reactor top dome is removed, and it is often necessary to adjust the water level within the reactor vessel. The level of the water in the reactor vessel can be adjusted by drainage from the vessel to the warm sump tank through the two taps on the side of the vessel. The upper drain tap is positioned for a level to accommodate normal shutdown tank work, and the lower drain tap is positioned for changing experimental equipment. The level in the reactor vessel must be dropped before the dome can be removed, so air is admitted through a vent valve on the top cap. An important safety aspect of the drain lines is the fact that the water cannot be drained below the reactor core by use of these two lines. The level of the lower drain tap still provides several feet of water shielding above the reactor core.

The primary coolant inlet and outlet lines are the only other two major lines that penetrate the reactor vessel. Here again, these lines enter and leave the reactor vessel at a point above the reactor core. This allows for some water shielding above the core even in the event of a major break in one of these two lines.

(2) Flow Distributor

The inlet 36-in. primary coolant line penetrates the reactor vessel and discharges its water into a flow distributor located inside the reactor tank. This flow distributor directs the flow of the primary coolant water into the vessel so that turbulence at the core inlet and hydraulic loads on the internal reactor components are minimized.

(3) Thermal Shields

The thermal shields protect the reactor vessel walls and concrete biological shield from excessive thermal stresses.

The three sources of heat considered were direct gamma radiation from the core, gamma radiation from capture of thermal neutrons, and the slowing down of fast neutrons.

The reactor primary coolant is a medium which removes and transports the heat removed from the internal thermal shield. This internal thermal shield is located in the reactor vessel outside the inner tank; the latter forms a wall around the reflector and also acts as a baffle for the exit of the primary water which must pass between the shells of the internal thermal shield before leaving the reactor vessel to enter the primary coolant outlet header.

The 3-1/2 in. thick lead external thermal shield has stainless steel cooling coils embedded in it and utilizes primary coolant flow to remove the head absorbed by the shield. The cooling water for the coils is tapped from the reactor inlet cooling water line and returned to the outlet line. The flow of the coolant through the coils can be controlled by a remotely operated control valve. To meet the design conditions of the biological shield, the coolant temperature at the thermal shield outlet should never exceed 125°F, and the ambient temperature outside the biological shield should never drop below 70°F.

(4) Experiment Penetration Leak Prevention and Detection System

There are several experiments that actually penetrate through the top and/or bottom heads of the reactor vessel. Two separate sets of packing are used to seal these penetrations against the internal pressure of the primary cooling water. In addition, a source of high pressure demineralized water is supplied to the penetrations at a pressure of approximately 250 psig. This water enters through a lantern ring which is located between the two sets of packing; thus, it is this clean demineralized water that is forced through the upper or lower packing if either of these two packings should develop a leak. There is no flow rate of this seal water except where a leak has developed. Therefore, the seal water flow rate to each experiment penetration is monitored periodically to determine the condition of the packing.

(5) Control Rod Leak Detection System

The control rod drive mechanism for the reactor penetrates the bottom head of the reactor vessel. Two sets of packing are again used to seal against the high pressure primary coolant water inside the reactor vessel. The lantern ring, located between the upper and lower sets of packing, has a connecting line to the warm drain system. Thus, any water that leaks past the upper packing is drained off at the lantern ring to the warm drain system, and the lower packing does not have to seal against any appreciable pressure. Water leakage from each control rod drive passes through a rotometer before it discharges into the drain system; therefore, any water leakage through the upper packing is monitored before it goes to the drain. The amount of leakage shown on the rotometers indicates the condition of the control rod drive packing.

c. Discussion of Important Operating Procedures

(1) Normal Shutdown Procedures

The primary system surge tank is isolated before the primary system is completely depressurized to prevent losing the water level in the surge tank. In this way, the surge tank remains at near normal operating conditions and is ready for service when the primary system is again repressured.

The degassing tank is located at an elevation which is higher than the top of the reactor vessel. This tank is open to the atmosphere; therefore, the degassing tank must be isolated from the primary system to prevent water from running from the degassing tank into the reactor vessel at the time that the reactor top dome is removed.

(2) Normal Startup Procedure

After the top dome is in place, the primary system is filled with demineralized water and thoroughly vented at all high spots in the system to remove all air possible. The degassing tank is not opened into the primary system until the system is liquid full and vented. The surge tank is not opened into the primary system until the pressure in the primary system is approximately equal to the pressure in the isolated surge tank.

d. Abnormal Conditions

(1) Electrical Power Failure

The primary system has several safety features designed to protect the reactor during a commercial power failure. The two major results of a power failure are: (a) the reactor is scrammed from electrical relays; and (b) the main primary cooling water pumps lose power and coast to a stop.

The following auxiliary actions also take place: (a) the operating emergency pump continues to run since it is on diesel generator power; (b) the bypass flow control valve automatically closes on power failure, and this action insures that all of the 2000 gpm emergency flow goes through the reactor vessel; and (c) the back pressure control valve automatically closes on power failure immediately stopping the flow of water from the primary system to the degassing tank.

(2) Major Break in the Primary System

There is a connecting line with two manual block valves between the fire water main and the primary system. This line could be used to add large quantities of water to the primary system in the event of a major break in the primary system.

3. Secondary Cooling System

a. General Description

The secondary cooling system is designed to remove heat from the demineralized primary coolant water through the primary heat exchangers. The secondary coolant water is, in turn, passed over a cooling tower where the temperature is reduced to within a few degrees of wet bulb temperature by evaporation. The volume of water in the secondary loop, including the stored water in the cooling tower basin, is 632,000 gallons. The quantity of water lost by evaporation or wind drift amounts to about three percent of the total flow.

b. Major Functions of Secondary System

(1) Flow

The flow of the secondary water is circulated through the secondary system by four pumps connected in parallel. Water is pumped from a coldwell underneath the pumps. The water flows into a common header to the four banks of heat exchangers, passing once through the shell side (see Figure 24). It then flows into another common return header which carries it to the cooling tower. (These headers are located in the secondary pipe tunnel.) After passing over the tower and into the tower basin, the water returns to the coldwell by gravity flow.

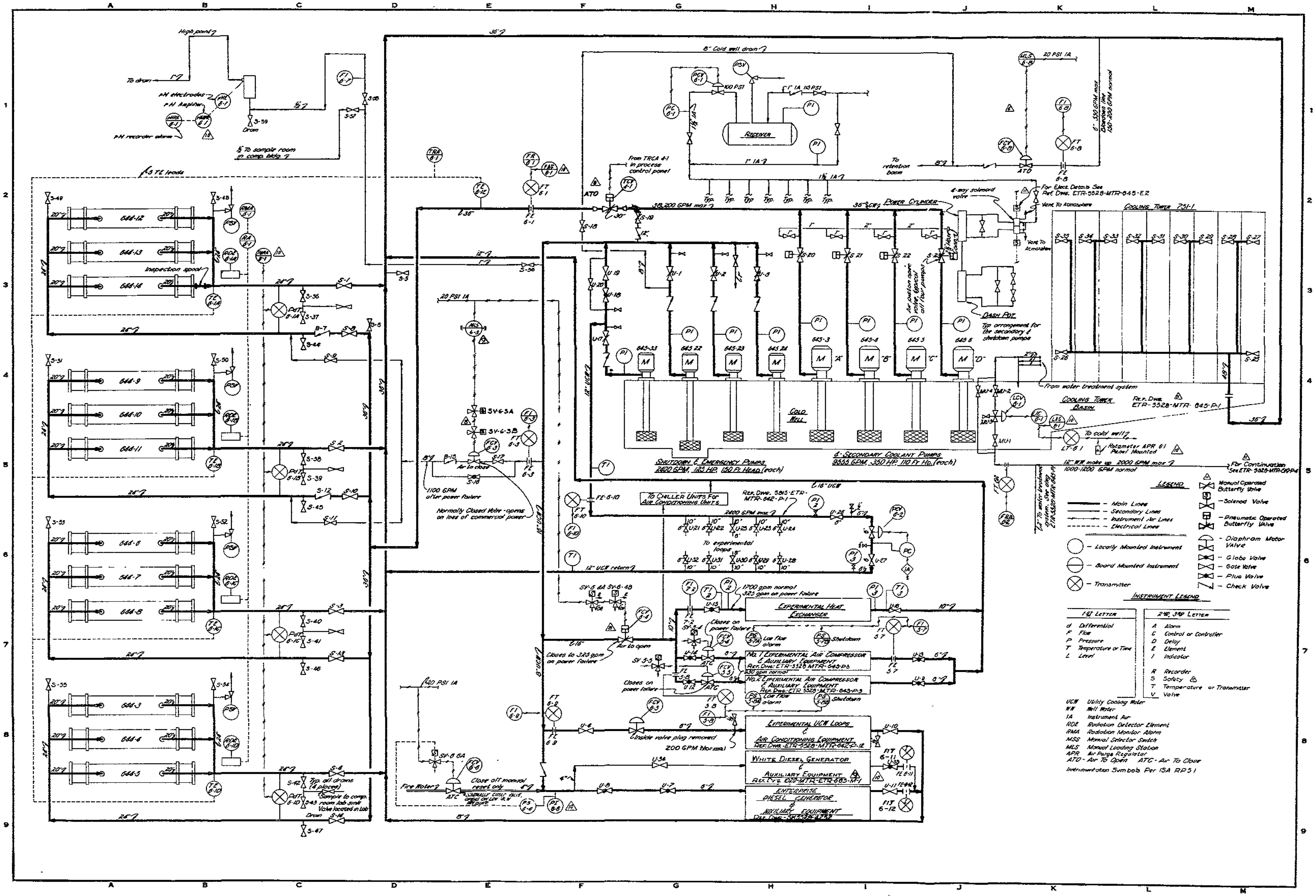

Figure 24

ETR Secondary Coolant System
Piping and Instrument Diagram

(2) Heat Removal

During normal operation, by means of the heat exchangers, the secondary system removes 175 MW of heat from the primary system.

A large wooden header delivers the water to a distribution system at the top of the cooling tower. The cooling tower is divided into nine bays, any one of which may be isolated from the water distribution system. Each cooling bay has a counter flow induced draft fan with a capacity of 542,000 cfm.. All fans but two have one speed forward and one reverse speed. The other two fans have two speeds forward and reverse. It is often necessary to reverse one or more fans during cold weather to prevent ice formation in the cooling tower. The fans are controlled from remote push-button stations in the process control room. The water is discharged through spray nozzles at the top of the tower and falls down through a network of redwood slats. The fans draw air from openings at the base of the tower and discharge it out the top. In this way, the cooling tower dissipates the 175 MW of heat to the atmosphere.

(3) Temperature

The flow in the secondary system is controlled by a butterfly temperature control valve. The flow of secondary water is varied to regulate the amount of heat which is transferred from the primary system. A temperature sensing element measures the temperature of the primary cooling water near the reactor inlet. This temperature signal goes to a temperature controller, which in turn positions the flow control valve in the secondary system to achieve the desired primary temperature. However, the basic function that is being controlled is the amount of heat that is removed from the primary system. The rate of heat transfer depends on the flow and temperature of the secondary cooling water. Therefore, the secondary flow rate can be indirectly regulated by varying the temperature of the secondary system. This allows the operator in the process control room to keep the secondary flow control valve within its operating range by regulating the temperature of the secondary water.

The temperature of the secondary water is controlled through the cooling tower. The cooling that can be achieved from the tower depends on the outside air temperature, the atmospheric condition, the amount of air pulled through the tower, and the water flow rate. Of these, it is the volume of air which is varied to regulate the temperature of the secondary water. Thus, the operator selects the number of cooling tower fans to be run in the forward direction to maintain a satisfactory secondary temperature.

(4) Radiation Detection

(a) Monitrons

The radiation of the secondary water is monitored at the outlet line from each heat exchanger. A radiation measuring unit is mounted in a well projecting into each of the four lines. (These lines are located in the secondary pipe tunnel.) The four radiation signals are recorded on the multi-point recorder in the process control room. An audible alarm sounds in both the HP office and the process control room when any one of the signals indicates that a small amount of radiation is present.

The purpose of this radiation detection system is to give a fast indication of any leak between the primary and secondary systems. The most probable place for such a leak to occur would be through the failure of a heat exchanger tube. The radiation element that first shows an increase would indicate which heat exchanger bank contained the break. Radioactive contamination in the secondary system would escape in the cooling tower and spread over the surrounding area; therefore, it is important that no appreciable amount of contamination is allowed to enter the secondary cooling water.

(b) Water Samples

As a back-up of the monitron system while the reactor is up, a 60 ml sample is taken once a day from the secondary side of each heat exchanger and delivered to health physics for a gross determination of beta-gamma activity.

(5) Cooling Tower Blowdown

The evaporation of the secondary water in the cooling tower removes water from the system, but does not remove the solids and chemicals with the water; therefore, the evaporation process continuously increases the concentration of solid material in the secondary water. An equilibrium concentration of total solids is established by purging some of the high solid concentration water from the secondary system and replacing it and the evaporation losses with low solid concentration water from the wells at MTR.

c. Abnormal Conditions

In case of a commercial power failure, the following takes place: (1) all four of the secondary pumps coast to a stop; (2) valves automatically open which divert the flow of the Utility Cooling water through heat exchanger banks "A" and "B". Two of the four UCW pumps are on diesel power. Hence, sufficient water is circulated through the secondary system to absorb and dissipate the reactor after-heat.

d. Water Treatment

(1) Acid System

Sulfuric acid is added to the coldwell to control the secondary water pH between 6.0 and 6.3. This pH range gives protection against the formation of sludges. A high pH will promote a type of corrosion attack which is localized in the form of pitting. Low values of pH increase the danger of trace corrosion of copper and redeposition of copper on the steel piping and heat exchangers. The specified pH range also is desirable from the standpoint of protecting the cooling tower wood against delignification.

(2) Dianodic System

Dianodic is the trade name for a chemical mixture containing phosphate and chromate ions. This is added to the secondary system to inhibit the deposits and pitting caused by raw water in contact with metal pipes.

(3) Chlorine System

Chlorine gas is injected into the secondary system to kill and inhibit the growth of living organisms, such as moss and algae, on the cooling tower and in the pipes. Enough chlorine is injected three times a week to reach a concentration of 1 ppm in the secondary system.

The chlorine gas cylinders and the chlorinator are contained in a separate room in the pump house. This room is equipped with an exhaust fan which draws air from the pump house, passes it through the chlorine room, and discharges it to the atmosphere. This is done to prevent any harmful concentration of chlorine from accumulating in the chlorine room. Any person entering the chlorine room is required to wear a special chlorine absorbing mask or use an air supplying respirator.

4. Utility Cooling Water (UCW) System (See Figure 25)

a. General

The utility cooling water system at ETR utilizes secondary water from the pump house coldwell and supplies it to plant and experimental facilities for heat removal. The water is then returned to the 36-inch secondary coolant return header to the cooling tower.

b. Normal Use

(1) Coolant to High Pressure Demineralized Water (HDW) Heat Exchanger and Clark Compressors

A 16-inch line leaves the UCW header in the secondary pipe tunnel and enters the compressor building from the north, through the foundation, under the grating, and then splitting to feed water to the two Clark compressors and the HDW heat exchanger. The high pressure demineralized water is used as a secondary coolant to remove heat from certain experimental facilities. UCW is used in the secondary side of the 10 MW heat exchanger to remove the heat picked up by the HDW.

(2) Coolant for Diesel Generators

The second loop of the UCW supplies the cooling water to the Enterprise and Superior diesel heat exchangers. The diesel generator system is included as part of the plant split bus power system, and one diesel is run continuously throughout a reactor cycle. Cooling water is required whenever a diesel is running and is used in the secondary side of heat exchangers cooling the jacket water and the lube oil.

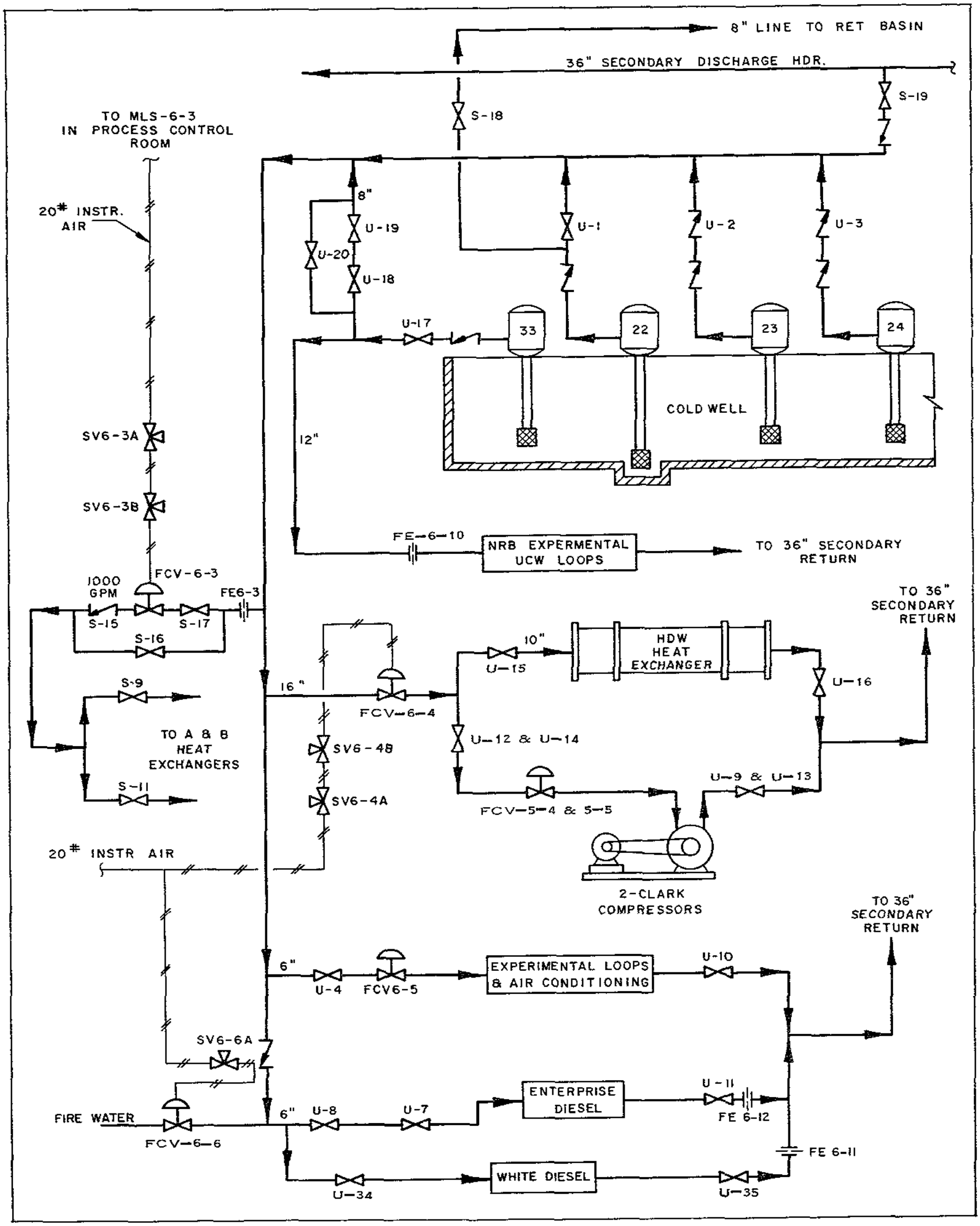

Figure 25

ETR Utility Cooling Water System

An emergency fire water line is provided for diesel cooling if UCW cooling water is lost.

(3) Coolant for Experimental Facilities

The third part of the original UCW system is a 6-in. loop that furnishes coolant for some of the experimental facilities in the basement of the Reactor Building. The inlet line enters the Reactor Building at the southeast corner of the console floor and drops down to the basement ceiling where the 6-in. supply and return loops are located. Cooling water from the supply loop passes through the experimental utilities and enters the return loop. On the north side of the basement and connected to the UCW loop is a 1-1/2 in. system which supplies UCW to the heating and ventilating rooms beneath the Office Building.

An additional 12-in. line has been added to the original UCW system. This overhead line supplies UCW to the experimental facilities on the south and west sides of the basement.

c. Emergency Use

During a commercial power failure, the Clark compressors shut down. The UCW normally required for their cooling is diverted by automatically controlled valves to the secondary side of "A" and "B" heat exchangers where it absorbs the after-heat of the reactor from the primary water until commercial power can be restored and the main secondary pumps restarted.

5. High Pressure Demineralized Water System (See Figure 26)

a. General

The pressurizing is supplied by a 3-in. line from the demineralized water header from the MTR-ETR make-up demineralizer unit. The 3-in. supply line enters the east side of the Compressor Building 643 and is fed to one of two pressurizing pumps (pumps operate on both commercial and diesel power). These pumps supply high pressure water to the following three separate systems: the pump gland seal system, the facility seal and chamber purge, and the experimental cooling loop.

b. The Pump Gland Seal System

This system consists of a 1-1/2 inch line which feeds water at approximately 205 psig to the gland seals of the primary coolant pumps, the degassifier and pressurizing pumps, and the emergency and shutdown pumps, thus preventing the leakage of contaminated primary coolant from the pumps. The flow of demineralized water to each pump is metered. If a leak develops, an alarm is actuated in the process control room.

c. The Facility Gland Seal and Chamber Purge System

This system consists of a 2-inch line which supplies the pressure on the lantern rings around facility penetrations through

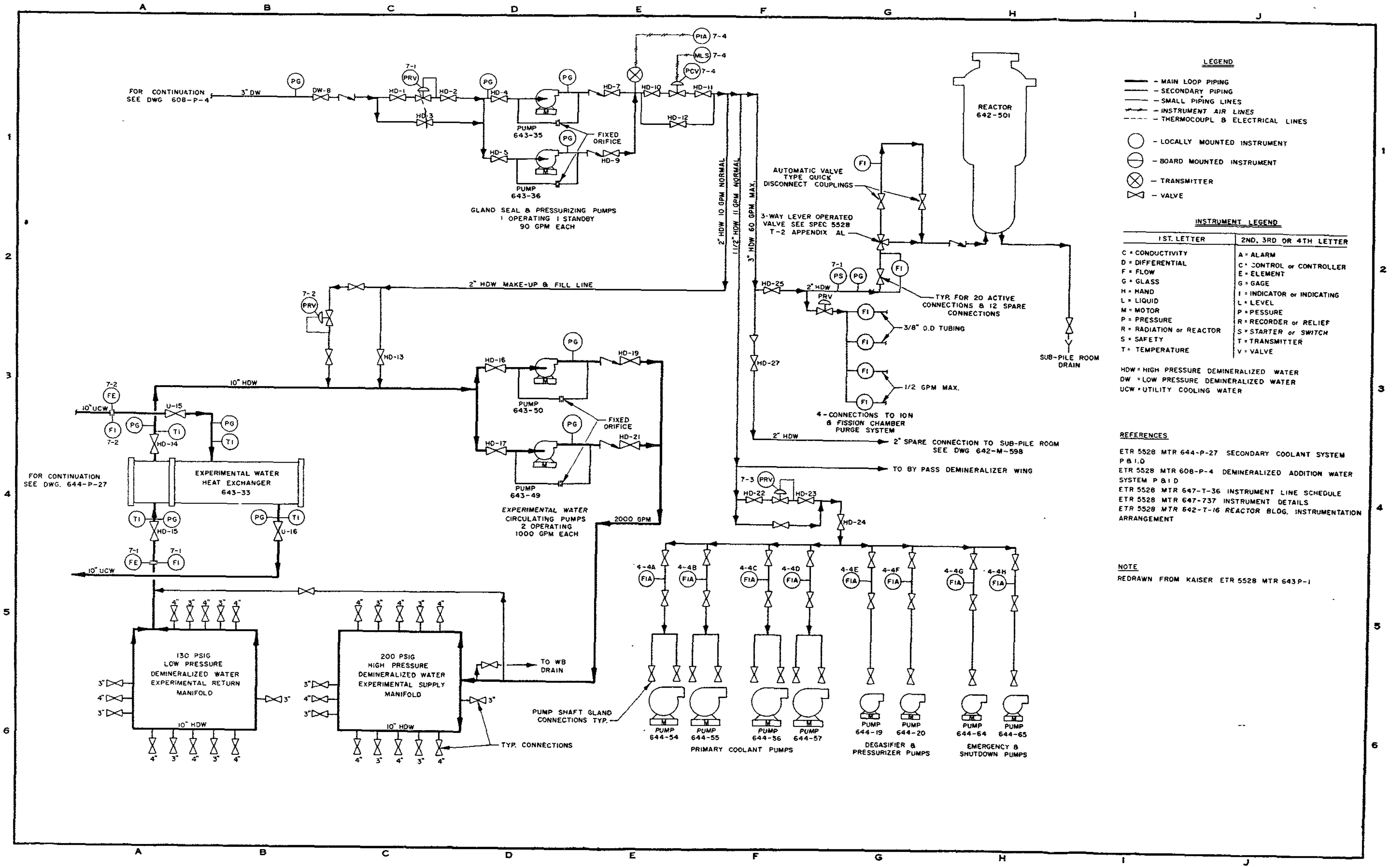

Figure 26

ETR High Pressure Demineralized Water Piping and Instrument Diagram the reactor top and bottom heads. Pressure in the system is maintained above vessel pressure to prevent leakage of contaminated coolant from the vessel.

The chamber purge system will supply a normal flow of 2 gpm of demineralized water at 25 psig to two fission chamber and two ion chamber housings. The housings are pipe risers that extend through the bottom head of the reactor to a position close to the grid plate. The purpose of this system is to fill the housing for shielding and to cool the chambers.

d. Experimental Cooling Loop (See Figure 26)

This system also receives its make-up supply through a 2-inch line from the pressurizing pumps. The experimental cooling loop consists of two 12-inch headers, a supply and a return, which completely circumvent the basement ceiling. Demineralized water from this system is used as a secondary cooling water for the experimental loop heat exchangers located within the cubicles. The return header carries the water back to the HDW heat exchanger located in the Compressor Building where the heat picked up in the cubicles is transferred through the heat exchanger to the utility cooling water loop for heat removal by the cooling tower*.

F. ETR Heating, Ventilating, and Air Conditioning System

1. Introduction

It is important that an HP be thoroughly familiar with the air circulation system of the plant in which he works to enable him to discuss with and make intelligent recommendations to operations personnel in preventing and controlling radiation hazards.

The heating and ventilating systems are designed so that if all systems are adjusted and working properly, air flow will be from clean areas to areas which may contain contamination or air activity, hence to the stack.

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* If a leak should develop in one of the experimental loop heat exchangers, it is quite probable that the highly contaminated water from the loop will leak into the HDW cooling system. As the "hot" water is carried into and moves along (the basement ceiling) through the return header, the radiation level will increase and be indicated by the RAMs, #19 on the south wall, #14 on the west wall, and finally by #11 and #12 on the north wall. If the situation persists the "hot" water will be carried, via the return header, to the HDW experimental heat exchanger in the Compressor Building, and the radiation field in this vicinity will noticeably increase. This will be indicated by RAM #5 located on a pillar at the west end of the heat exchanger and RAM #6 located on a pillar about 10 yards east of the heat exchanger. The leak can be easily pin-pointed by checking the radiation of the HDW return lines from the cubicles. The cubicle having the greatest differential reading between its supply and return lines will contain the leak.

2. Reactor Building First Floor System

This system is designed to circulate first floor air four times per hour and to maintain an area temperature of 65°F. Two of these hourly air changes shall be from fresh outside air and two by recirculation. This circulation is effected by means of one supply air fan with a capacity of 48,000 cfm and one exhaust fan with a capacity of 24,000 cfm. The exhaust duct and fan are located in the ceiling of the Reactor Building. The supply fan is located in the heating and ventilating rooms of the Office Building basement (see Figure 27).

Air flows are determined by the position of the dampers controlling the outside air, return air, mixed air, and supply air. Maintenance of the desired atmospheric pressure in the first floor area is dependent upon balance between supply and exhaust air volumes.

The atmospheric pressure of the Reactor Building first floor should be maintained at a slightly negative pressure in relation to the Office Building, the Compressor Building, and the Electrical Building so that the air leakage is from these clean areas into the Reactor Building.

3. Reactor Building Console Floor and Basement Area System

This system is designed to heat and ventilate the console floor and the basement areas of the Reactor Building. The system will maintain an air change rate equal to six times the total cubicle area per hour. To maintain this rate, the cubicle exhaust fans will exhaust approximately 15,200 cfm to the waste gas stack, while the console floor supply fan is recirculating 19,100 cfm and supplying 15,100 cfm of fresh air. The total exhaust exceeds the total fresh air supply and maintains a slightly negative pressure in the basement and cubicle areas in relation to the console floor and the main floor.

The exhaust air flow route is from the console floor through rectangular openings along the perimeter of the basement ceiling, to the cubicles, and then drawn into the cubicle exhaust duct by the cubicle exhaust fans (see section 14) and expelled to the waste gas stack via a continuation duct (see Figure 28).

4. Reactor Control Room System

This system is designed to provide a total air supply to the control room of 3650 cfm through three ceiling diffusers.

Return air to the unit mixing box is at the rate of 3000 cfm. Air is leaked to the Office Building corridor at the rate of 650 cfm. Fresh air makeup in the mixing box is also 650 cfm.

5. Office Building System

This system is designed to maintain six changes of air per hour for the office section of Building 647. Two of these changes

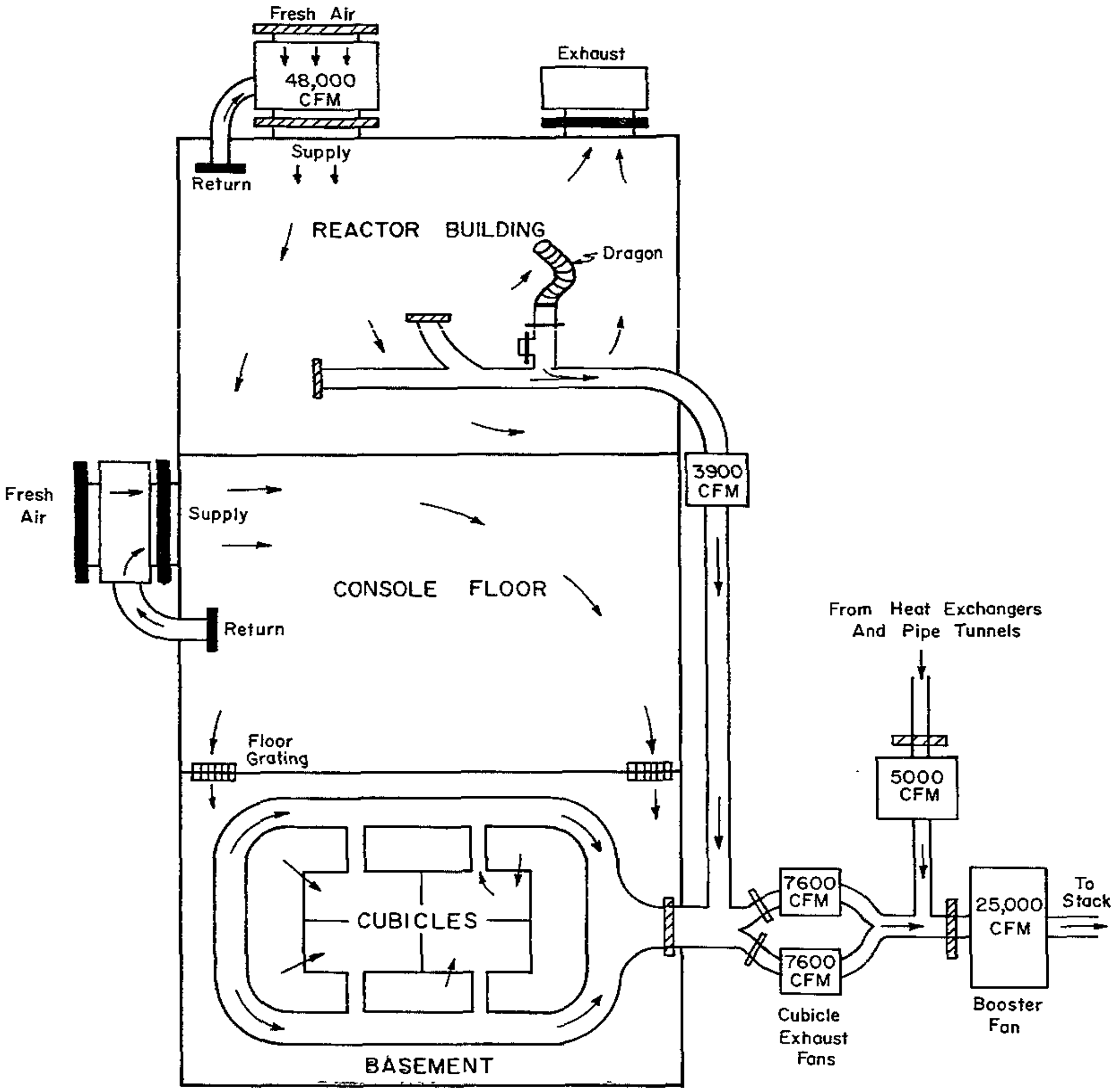
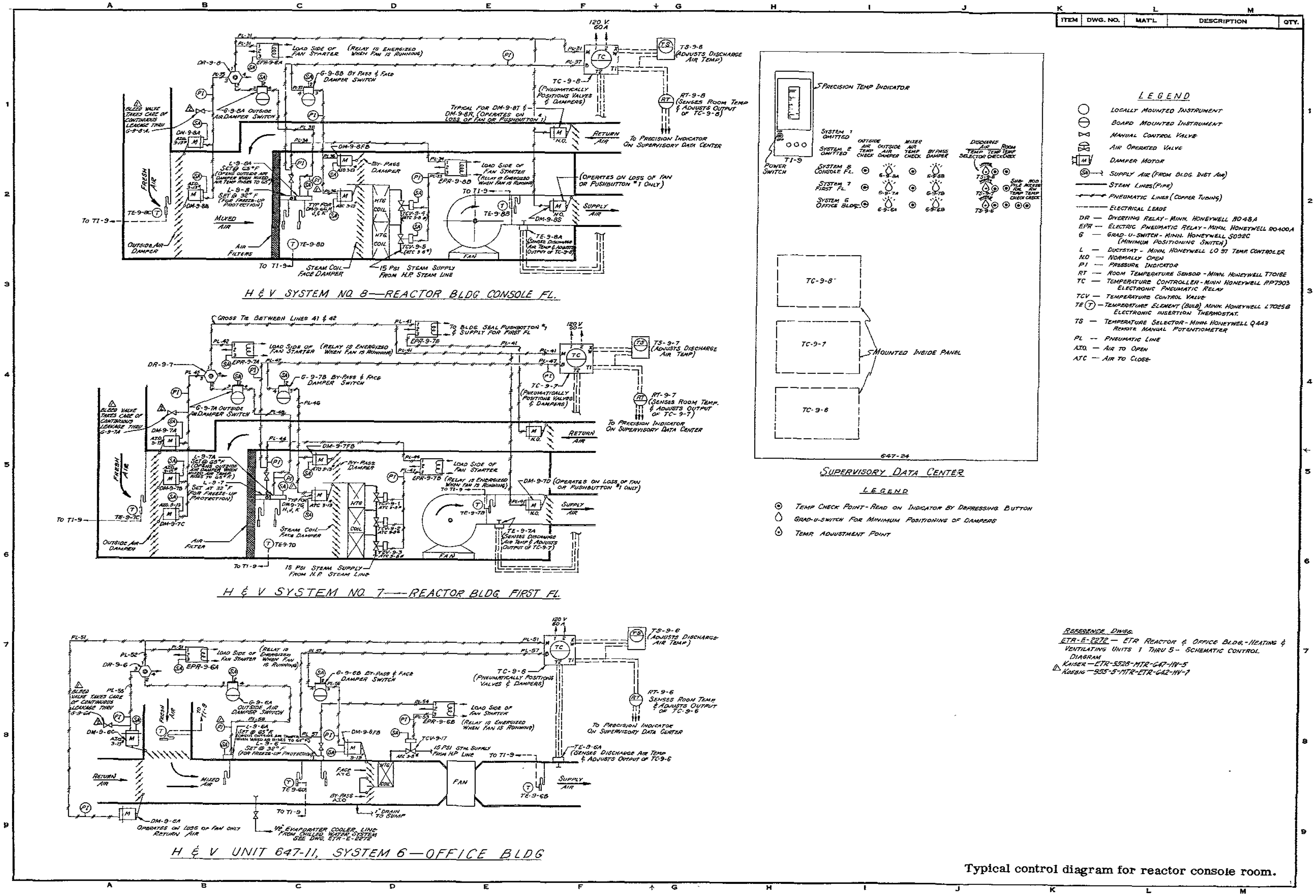


Figure 27

Normal Building Air Circulation For ETR



Typical control diagram for reactor console room.

Figure 28

Typical Control Diagram
For Reactor Console Room

shall be fresh air. It also maintains office temperature at 70°F. In addition, it provides twelve changes of air per hour for the change room.

This system includes a supply air fan rated at 5160 cfm which supplies 2690 cfm fresh air and recirculates 2470 cfm. The building exhaust fan is rated at 3000 cfm. An additional fan in the change room exhausts air to the main exhaust duct served by the building exhaust fan.

The 2690 cfm of fresh air from the supply fan, plus approximately 650 cfm leaked from the reactor control room, exceeds the Office Building exhaust rate. This creates a positive pressure and insures that air currents will travel from the clean area (Office Building) outward into areas more likely to contain contamination.

6. Amplifier and Instrument Repair Room System

This system is basically the same as that of the Office Building but includes a cooling unit which circulates chilled water through a cooling coil in the air supply duct as required.

The supply air fan will furnish a total of 3560 cfm to the system area; 1000 cfm shall be routed to the instrument repair room; 2560 cfm to the amplifier room; 2180 cfm is returned to the unit mixing box from the amplifier room; and 820 cfm from the instrument room; and the balance of the total supply, 560 cfm, will be leaked to surrounding areas. This leak rate requires fresh air make-up to the mixing box at the same rate.

7. Sub-Pile Room System

This system is designed to cool the sub-pile room to a maximum of 105°F. This is accomplished by supplying chilled water from the chiller units to each of two Spotair cooling units. The rate of chilled water flow through each unit coil is 8 gpm, entering at 45°F and leaving at 50°F. Each unit is equipped with a direct drive, multiblade centrifugal type fan.

A connecting duct to the cubicle exhaust loop in the basement area exhausts air from the room. Normal air supply to this room is by leakage only, and room pressure shall be negative in relation to the main basement area.

8. Control Rod Access Room System

Air supply and exhaust is identical to the sub-pile room system except for lower cooling unit capacities and a lower chilled water flow rate at each chiller of 2.5 gpm.

9. Chilled Water System

The chilled water system serves the reactor control room, the amplifier room, the sub-pile room, and the rod access room cooling coils with 45°F to 50°F chilled water. The heat from the chillers is removed by utility cooling water at approximately

70°F. In the event the utility cooling water is cut off to the chillers, a tie-in from the building fire water system will supply cooling water.

10. Compressor Building System

This system is designed to maintain two fresh air changes per hour. Fresh air intake is through four roof-mounted evaporative coolers connected to the four unit heaters by ducts and mixing boxes. Fresh air and return air rates are regulated by the manual setting of the mixing box damper. Used air is exhausted through five powered roof ventilators, each having a capacity of 10,500 cfm. These fans are manually controlled and may be individually operated as required. Winter heating is regulated by temperature control valves in the steam supply line to each unit heater coil. Summer cooling and ventilation is effected by evaporative cooling of intake air, full use of the powered roof ventilators, and by opening the adjustable wall louvers on the north side of the building.

Since both supply and exhaust fans are manually controlled, it is quite possible and sometimes happens that the exhaust rate far exceeds the supply rate. When this happens the atmospheric pressure within the Compressor Building is reduced below that of the Reactor Building. This is very undesirable for air (possibly contaminated) will leak from the Reactor Building into the Compressor Building.

Air activity in the sample room is another hazard caused by the unbalanced adjustment of the supply and exhaust fans of the Compressor Building. The reduction in the air supply reduces the efficiency of the sample room hood exhaust fan sufficiently to allow air activity (always present within the hood) to escape into the room. For this reason, it is essential that health physics monitor the atmosphere of the sample room for radioactivity.

11. Heat Exchanger Building and Pipe Tunnel System

This system ventilates the Heat Exchanger Building and primary and secondary pipe tunnels. The heat exchanger bay section of Building 644 is heated by two horizontal propeller type unit heaters. An exhaust fan rated at 5000 cfm draws air from the Heat Exchanger Building and discharges it to the suction side of the cubicle exhaust booster fan (see Figure 27). The only air supply is leakage through the pipe tunnels.

12. Electrical Building System

Winter heating of the main floor is maintained by two industrial-type unit heaters equipped with mixing boxes. Steam supply to the unit heater coils is regulated by its related thermostat. Fresh air intake shall be equal to the total cfm exhausted from the battery room and force vented from the cable vault.

Summer cooling of the areas is effected by adjusting the mixing box damper to route intake air from the evaporative coolers. Additional ventilation may be obtained by manually opening the gravity vents in the ceiling.

13. Experimental Air Filter Pit and Tunnel

Tunnel cooling and ventilation during summer is accomplished by taking air through an evaporative cooler, rated at 8000 cfm, located at ground level at the Reactor Building end of the tunnel. A second evaporative cooler, rated at 6000 cfm, mounted on the roof of the filter pit admits air for cooling the filter pit area. Air is exhausted through two tunnel exhaust fans rated at 7500 cfm each.

This system also includes a recirculation fan and mixing box with an associated damper and two electric unit heaters. The recirculation fan operates only in the winter to prevent filter pit temperature from falling below 50°F. A modulated thermostat actuates the damper motor opening and closing the outside air intake damper in the mixing box to provide necessary mixing of the outside and recirculated air to prevent freezing air from entering the room.

14. Cubicle Exhaust System (See Figure 27)

The cubicle exhaust system is a continuation of the basement heating and ventilating system. The air flow route is from the console floor to the basement through openings in the basement ceiling. From the basement it leaks into the experimental cubicles, and then into the cubicle exhaust duct. Two cubicle exhaust fans located between the console floor and the Electrical Building, each rated at 7600 cfm, discharge to the suction side of a booster fan. The booster fan, rated at 25,000 cfm, is in a room located on top of the Heat Exchanger Building and discharges to the waste gas stack via a continuation duct*.

Coming through the reactor building floor are three exhaust ducts located at the working canal, storage canal, and the south side of the reactor top. The latter of these exhausts the nozzle trench while the reactor is at power. When the reactor is down and the refueling platform is on, this duct is extended by means of a damper and a flexible steel reinforced composition tube called the "Dragon", and is connected to the adapter of the refueling platform to exhaust air from the reactor tank. This minimizes the spread of fission products during reactor shutdown. The small duct (small dragòn) located at the working canal is used to exhaust the dome as it is being removed.

These three ducts converge into one single duct on the console floor, and within the duct is a two-speed Axivane fan which discharges into the suction side of the cubicle exhaust fans. The control buttons for this fan are located on the south side of the working canal parapet.

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* When the reactor is at power, there is always high level air activity in the fan rooms.

15. Effluent Discharge Monitoring

To prevent the inadventent release of excessive radioactivity to the atmosphere, the stack discharge is continuously monitored for both particulate and gaseous fission products.

For monitoring particulate activity, a continuous air sampler is used to collect the particulate material onto a continuous strip of filter paper. The filter is then moved past a scintillation detector.

After the removal of the particulate from the air stream, the sample is routed to a gas chamber consisting of a six-inch diameter by six-inch long cavity within a lead shield. Centered within this cavity is a similar scintillation detection head for monitoring gaseous activity.

The monitoring equipment is located in the cubicle at the base of the stack with the exception of the recorders which are on the reactor control panel. Each recorder has a pre-set alarm switch which operates its respective annunciator both in the control room and the HP office. Health physics is responsible for keeping the instruments calibrated and for alerting IDO Health Physics if the effluent discharges exceed the currently safe operating limits.

16. Building Seal Operations

Two "Building Seal Pushbuttons,"* No. 1 and No. 2, are located on the reactor control console in the reactor control room. Pushbutton No. 1 is used when conditions require that the building be purged of contaminated air. It closes dampers and shuts down fans, discontinuing all recirculation to prevent the contamination of the heating and ventilating systems. The air flow is from the Reactor Building downward through the circular stairwells to the console floor and then through the floor gratings to the basement and is exhausted by the cubicle exhaust (see Figure 29).

Pushbutton No. 2 closes and shuts down the remaining dampers and fans to seal the building off completely from the outside atmosphere and stop all circulation.

Another arrangement used to clear the Reactor Building main floor of low level and short half life air activity is to shut off the supply fan, close the recirculation damper, and open the large truck door. This will clear the building of air activity without contaminating the air ducts. It is sometimes advisable to set up this arrangement prior to pulling the dome or an experiment, etc., from the reactor tank which is expected to produce an air activity hazard.

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* Keep in mind that health physics can make suggestions and recommendations, but the responsibility for actually operating these buttons lies with (and only with) the shift supervisor of Operations.

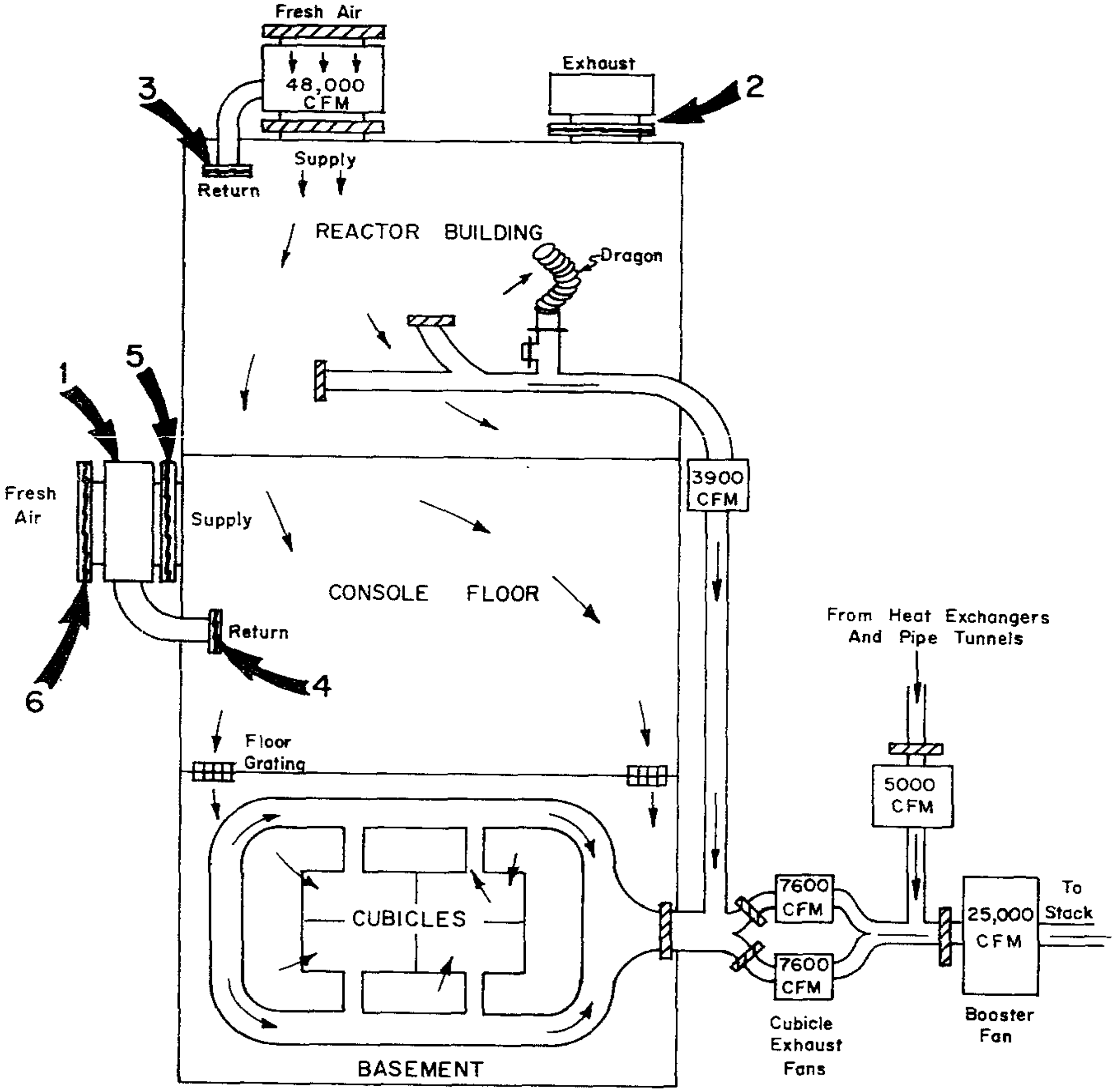

Figure 29

Building Purge Air Circulation For ETR

The following are controlled by push button number 1:
1) console supply fan
2) first floor exhaust fan & building seal damper
3) first floor return air damper
4) console floor return air damper
5) console floor supply air damper
6) console floor outside air damper.

G. ETR Building Effluent Control

Three general classes of liquid wastes are discharged from the ETR. These are cold effluents, warm effluents, and hot effluents.

1. Cold Effluents (See Figure 30)

Cold effluents are those which are considered as never containing radioactivity; for example, cooling tower purge and steam condensate. Such effluents contain no activity and are pumped to the south end of the east MTR retention basin or to the cold waste disposal well located near the retention basins.

2. Warm Effluents

Warm effluents are those which normally have a small amount of radioactivity such that the material is within the allowable tolerance for leaching into the soil or can be brought economically within this tolerance by diluting or by holding for short-term decay of radioactivity. Material falling within this class includes reactor primary water following normal operation, canal drain water, access tunnel drains, pipe tunnel drains, etc.

a. Warm Effluent Disposal

These effluents enter collector piping leading direct to a 5000 gallon "warm" sump tank. The lowest source, the sump in the control rod access tunnel, requires a pump; the remaining drains flow by gravity (see Figure 30).

b. Warm Sump Tank Discharge

The 5000 gallon warm sump tank located in the tank area beneath the northeast basement floor has two sump pumps rated at 200 gpm at 110 ft. head. These pumps can be manually operated; however, they are normally operated automatically by remote level indicating devices. Either pump can be selected to start first with the second pump starting at a higher tank level. Discharge piping is 4-in. stainless steel through a horizontal swing check and a remote operated plug valve. Discharges of these two pumps connect to a common 4-in. header which penetrates the sump tank exterior wall, rises to within 5 ft. of finished grade, and terminates at the north end of the MTR retention basin. The warm effluents may also be pumped directly to any of the four MTR hot waste storage tanks.

3. Hot Effluents

Hot effluents are those which are above the radioactivity tolerance for disposal as defined for warm effluents, and frequently contain sufficient quantities of long-lived radioisotopes to make diluting or holding for radioactive decay infeasible. The principal source of this class of effluent includes experimental loop-flushing liquids and possible radioactive liquids used in the loops.

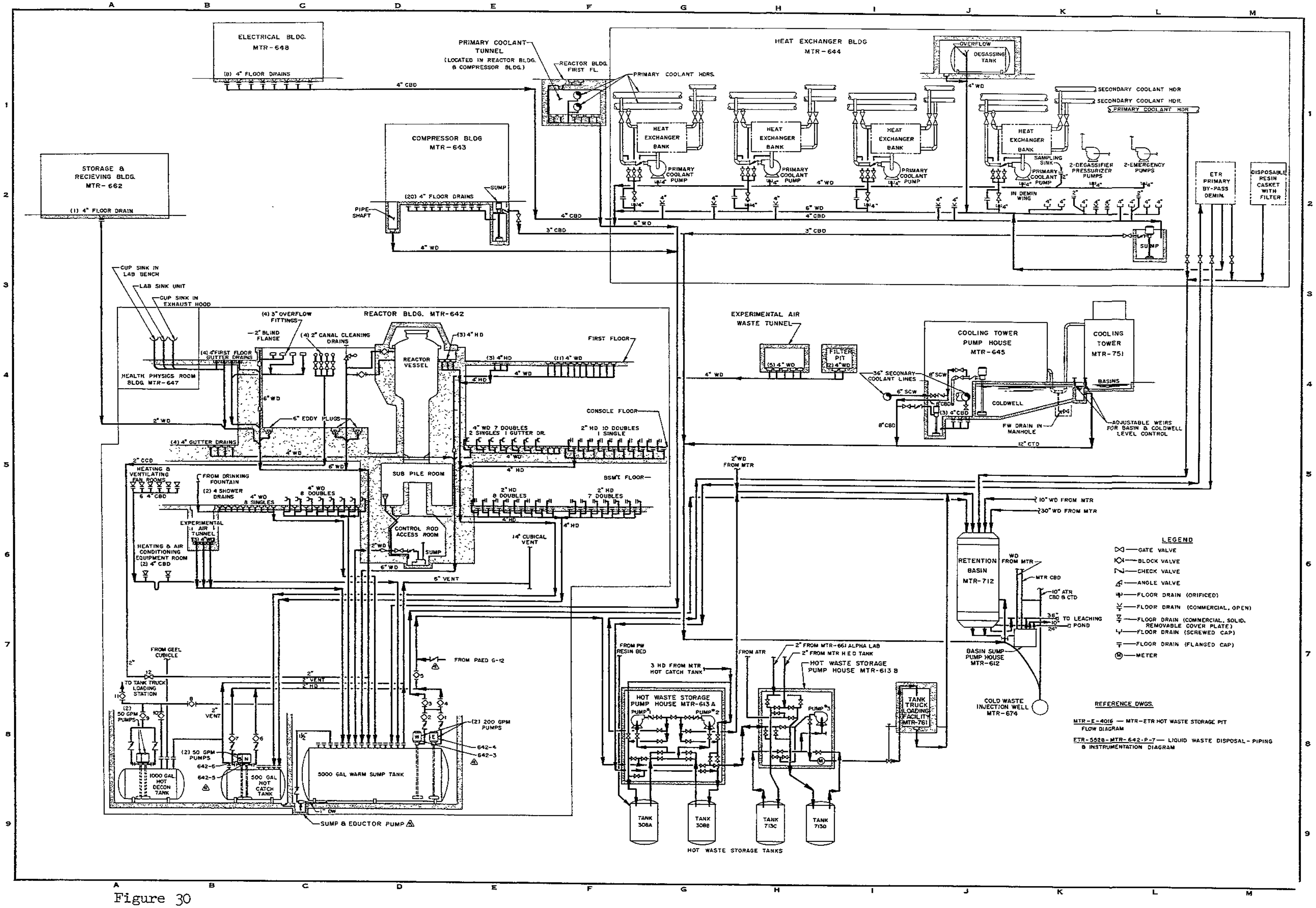

Figure 30

ETR Liquid Waste
Disposal Piping Diagram

a. Hot Disposal

Hot effluents are on a separate collection system draining into a 500 gallon hot catch tank. This tank acts as a sump from which hot wastes can be pumped to the MTR 10,000 gallon hot-waste storage tanks. No provision is made for sampling or neutralizing hot wastes in the 500 gallon catch tank.

b. Hot Catch Tank Discharge

The 500 gallon "hot" catch tank also located in the tank area has two sump pumps rated at 50 gpm at 75 ft. head. These pumps can be manually operated; however, they are normally automatically operated by remote level indicating devices. Normal operation requires only one pump with the other as a backup that starts at a higher tank level. Discharge piping is 2-in. stainless steel through a horizontal swing check and a remote operated plug valve. The discharges of these two pumps connect to a common 2-in. header which ties into a 4-in. line and serves as an emergency discharge from the 5000 gallon warm sump tank. This 4-in. stainless steel line penetrates the sump tank exterior wall, rises to within 5 ft. of grade, and terminates at the MTR Hot Waste Storage (see Figure 30).

c. Decontamination Tank

A 1000 gallon hot decontamination tank also located in the tank area is provided to collect decontamination solutions from certain experiments. This tank acts as a sump from which hot decontamination waste can be pumped to either the MTR hot waste storage or to the tank truck loading station. A sample connection is provided for sampling the waste in the decontamination tank.

4. Reactor Drain Lines

On each floor of the ETR Reactor Building are located numerous warm building drains labeled "WB" and also numerous hot experimental drains labeled "HED."

a. First Floor Drains

There are a total of six hot drains on the first floor, three of which are located in the nozzle trench. Four of the eleven warm drains are located in the canal gutter. Warm drains are also provided for the HP office.

b. Console Floor

Four of the nine warm drains are located in the canal gutter. The other warm drains and the eleven hot drains are located at various places in the floor and walls.

c. Basement Floor

In the basement there are sixteen hot drains and sixteen warm drains which empty into one of the two pairs of hot and warm drain lines. One pair of lines runs adjacent to the sub-pile room, and the other pair is located near the exterior wall of the cubicle area.

d. Miscellaneous

Several drains in the basement and on the console floor have twin connections. The twin connections include one connection for a semi-permanent pipe connection from experiments and one for collecting water from the floor. Flush mounted caps are provided to close inlets when not in use. The pipe tunnel and safety showers are connected into the warm drainage system.

e. Drain Line Exhaust

The "warm" sump, the "hot" catch and the hot decontamination tanks are tied into the cubicle exhaust system. This maintains a negative pressure on the tanks for the removal of gases. This also maintains a negative pressure on the warm and hot drains throughout the building to prevent the escape of air activity when a drain cap is removed. Since there are no traps in the drain lines, it is imperative that drain caps be kept in place to maintain the negative pressure*.

5. Tank Pit

This pit is located under the northeast basement floor.

Access is allowed only during reactor shutdown periods. Health Physics monitoring is required for entry, and surveillance is required during pumping operations due to loss of shielding when the water level is lowered over the radioactive accumulation in the bottom of the tanks. These areas are also highly contaminated and require Anti-C clothing including latex foot wear. An area radiation monitoring head is located directly over the tanks to sense any changes in the general radiation fields.

6. Liquid Waste Tolerances

Regulations governing radionuclide disposal are established by the USAEC and are subject to change and revision. The maximum allowable concentrations which may be released to the water table can be computed from the current AEC chart. In constructing this chart, the estimated dilution, soil sorption, and subsurface flow rate factors have been taken into consideration. The maximum

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* If, due to a malfunction or a power failure, the sump pumps ceased to work; and if by chance the sump tank high level annunciator were to go unheeded, water would back up the drain lines flooding the rod access room with contaminated water accompanied by high level air activity. Water would also back up the cubicle exhaust line stopping the air flow and allowing air activity to be emitted from all open drain lines such as the canal drains on the main floor. If the water were to back up high enough, it would be sucked into the basement cubicle exhaust header and then leak out onto the basement floor from the open butterfly valves.

allowable concentration for relatively long lived ($T_{1/2} > 1000$ days) waste materials that might find their way to the water table is three times the drinking water tolerance on a monthly average. On rare occasions, up to 10 times the drinking water tolerance may be dumped; but the monthly average must not exceed three times the drinking water tolerance. To discard material greater than 10 times the drinking water tolerance, special permission from the Idaho Operations Office, USAEC is required. Drinking water tolerance for mixed unidentified fission products is taken to be 1×10^{-7} microcuries per milliliter. For waste in which some or all of the radioisotopes have been identified, the drinking water tolerance is determined from the maximum permissible amounts of radioisotopes as given in Table 3 of Handbook 69, U.S. Department of Commerce, National Bureau of Standards, or by using the method described in Table 5 of that document.

7. Waste Disposal System

The TRA waste disposal system provides sufficient flexibility to practically eliminate the possibility of above tolerance liquid wastes being discharged into the leaching pond. If the MTR health physics section determines that the activity of the liquid waste is above leaching pond tolerance, there are three alternate possibilities for disposal: (1) if the half life of the radioactive material contained in the water is relatively short, it is stored in one of the MTR hot storage tanks and allowed to decay until the activity is such that it can be safety pumped into the leaching pond; (2) if, however, the activity of the waste is long lived, it is normally shipped to the Chemical Processing Plant where it is processed and stored; and (3) it may be pumped through the ETR by-pass demineralizer as explained in the next paragraph.

8. Clean-Up Effluent Waste

A 3-in. clean-up effluent waste line runs from the MTR hot waste storage tanks to the ETR by-pass demineralizer. The fluid may be discharged into the north end of the MTR retention basin, or it may be returned to the hot waste storage tanks. Clean-up is used only when the contents of the MTR hot waste storage tanks are excessively radioactive and it is necessary to discharge the contents. The system will concentrate the activity from the hot waste in the ion exchange resin of the ETR by-pass demineralizer. The resin is then disposed of in the NRTS burial ground.

H. Experimental Loops

1. General Description

An experimental loop is an assemblage of equipment which provides a specialized circulating environment in which the irradiation of an experimental sample can be accomplished.

These samples, with few exceptions, are fuel assemblies or other materials which are being tested for future use in a reactor. Each loop is designed to simulate the conditions of the reactor, yet to be built, for which the fuel assembly or other material being tested is intended.

The controls and instrumentation for the loops are located on the reactor console floor. The piping and miscellaneous equipment for loop operation are located in the experimental cubicles.

2. In-Pile Tubes

The in-pile tubes penetrate vertically the active lattices of the core. They actually consist of a pressure tube containing the sample and the circulating coolant within a larger diameter tube to form an annulus. There are two reasons for this double jacketed construction: (1) the annulus, being gas filled, acts as an insulating buffer and protects the pressure tube from the excessive thermal stresses which would be created if a single tube were used to separate the systems which operate at great differences in temperature and pressure; and (2) since the annulus is purged periodically, any leak which may develop is readily detected, thus the mixing of the two systems can be avoided.

3. Types of Loops

Experimental loops can be classed by the type of coolant medium used. Although most of the loops at ETR have been high temperature and pressure recirculating water loops, other coolants such as gas (air) and liquid metals have been used.

a. Air Cooled Loops

The two 15 lb/sec. Clark compressors and the three 8 million Btu/hr. Thermal Research Corporation air heaters located in the Compressor Building were installed for the purpose of furnishing air up to 300 psig and 1200°F for the single pass air-cooled loops. After passing through the reactor, the air is exhausted via the experimental effluent exhaust system to the stack.

b. Water Cooled Loops

Most of the water cooled loops are recirculating closed loops. The water is pumped from the cubicle up through one of the vertical conduits within the biological shield. It enters the reactor vessel via an access nozzle (located in the nozzle trench). It then flows down through the in-pile tube, cooling the sample, and makes exit through the bottom head of the reactor* into the sub-pile room. From the sub-pile room, the loops are routed, via access holes, back into the experimental cubicles.

4. Loop Experiment Removal

Each shutdown usually involves the change out of one or more of the loop in-pile experiments. No two removals are exactly alike, and to prevent damage to the experiment and tube, Maintenance and Operations personnel are required to follow specific written procedures. The experiments are either removed by lowering a receiving

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* Some of the more recent loops are re-entrant type loops which both enter and exit through the same access nozzle near the top of the reactor.

cask into the tank or tank extension, or the end of a specially made cask is mated to the "5-B-Block" shielding plug which fits over the reactor top. The experiment is then drawn up into the cask by means of a windlass. Since the irradiated section of the experiment is always extremely radioactive, there are always hazards involved. Consequently, the operation should be monitored by at least one and preferrably by two HP technicians to safeguard personnel from the collimated beams and air activity which may result as the experiment is drawn up into the cask.

5. Experimental Cubicles

a. General Description

Some of the cubicles are divided into two separate compartments: a primary cubicle and a secondary or access cubicle. In most cases the secondary cubicle houses the sampling facilities, the make-up pumps, and certain other miscellaneous instruments and equipment.

Within the primary cubicles are located the pumps which circulate the coolant through the loops, surge tanks for maintaining the desired pressures, filters and/or ion exchange columns for maintaining desired purity of the coolants, line heaters and heat exchangers for controlling the loop temperatures, plus the necessary piping and valving.

b. Heat Transfer

Within a typical loop heat exchanger, the heat is dissipated to either the HDW system or to an intermediate dowtherm* system which in turn transfers the heat by means of still another heat exchanger to the UCW system.

c. Radiation and Safety Considerations

Fission products which are always present in a loop coolant while the reactor is up to power cause extremely high radiation fields within the primary cubicles. Consequently, the walls are made thick enough to reduce the radiation field outside to a safe level.

The primary experimental cubicles are closed during reactor operation and are entered only in extreme emergencies. Entrance is not only hazardous radiologically but also from a safety standpoint, due to the high temperatures and pressures at which the loops are operated. Maintenance work is always scheduled during reactor down time. However, an emergency may make it necessary for personnel to enter a cubicle while the reactor is up to power. The hazards thus encountered may be minimized by following such rules as: (1) if it becomes necessary to do maintenance work on a pressurized loop, that part of the loop should first be isolated

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* Dowtherm is used because of its high heat transfer and low corrosion properties. Also, its high boiling point makes possible a low operating pressure even at high temperatures.

and depressurized; (2) only the most extreme emergencies should warrant personnel entering cubicles while the loops are at temperature and pressure. When this is done, a safe work permit should first be processed through higher eschelon supervision; (3) an insulated coat and hat, a face shield, respirator, boots, and asbestos gloves should be worn. The protective clothing will give temporary protection against a shower of steam. A second man dressed in protective clothing must stand-by outside the cubicle ready to assist in case of an accident.

Following shutdown, the cubicles are opened and surveyed. To comply with a maintenance supervision request, a cubicle survey sheet is color coded and placed at the doorway of each cubicle.

The color code to be used is as follows.

Uncolored	0 - 30 mr/hr
Green	30-100 mr/hr
Red	> 100 mr/hr with spots heavily colored to indicate sources of unusually high radiation.

The radiation fields may vary from day to day. Hence, these survey sheets must be kept up-to-date.

6. Loop Water Samples

Whenever loop water samples are taken, both an HP and a reactor engineer must be present. The HP assists by determining the direct radiation level of the sample and is responsible for giving safety advice to the personnel involved. He should monitor for direct radiation and air activity. Afterward, he should check both personnel and the area for contamination.

BIX (before ion exchange) samples are taken at least once during each shift. The comparative radiation level and half life gives an indication of the condition of the experiment. Fission breaks within the loop will be reflected by a considerable increase in activity. In the event of a fission break, precautions should be taken to prevent excessive exposure to the hands of the reactor engineers doing the sampling.

AIX (after ion exchange) samples are taken less frequently and are used for chemical analysis and for determination of the ion exchange column efficiency.

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CHAPTER IV

ADVANCED TEST REACTOR

A. Description of the ATR

1. Early History

The Advanced Test Reactor (ATR) was built by the U.S. Atomic Energy Commission at the National Reactor Testing Station to incorporate ideas developed through the use of the MTR and the ETR. A two or three reactor approach to the design was taken in the early stages of concept work. This was modified to a four lobe, serpentine fuel core arrangement which met all requirements of the Division of Reactor Development. The design criteria used in development of the final design concept were: (a) ATR will be a four lobe, multiflux trap reactor; (b) the reactor will be capable of operating with controllable power distribution between lobes; (c) control shall be accomplished in such a manner as to preserve at least a cosine distribution of flux throughout each cycle of operation; (d) the reactor shall be a generalized test reactor, but must meet Navy Reactor requirements as defined; and (e) the location is northwest of the MTR-ETR complex.

2. General Description

a. Buildings

The reactor building covers an area of approximately 200 feet by 200 feet, while the substructure extends approximately 60 feet below grade.

The building is divided into two basic types of areas, gastight and non-gastight. Although designated "gastight" these areas are perhaps better designated as low leakage areas. This feature was made a part of the design with the objective of containing, under controlled conditions, any releases of airborne or gaseous radioactivity from the reactor.

The areas have been created by application of special construction techniques such as seal welding, gasketing, caulking, and by use of special inflatable seals on sliding doors. The relationship of the ventilation system to this design will be described in a later section.

The reactor "room", on the ground floor (Figure 31), is 88 feet by 100 feet and occupies the south central portion of the building. This area has been kept as clean and unencumbered as possible to facilitate decontamination and washdown.

Also on the ground floor is a utility area which houses a process control room and miscellaneous offices, heating, and ventilating equipment. A storage and laydown area which contains a tool room and a floor area with several hatch covers which lead to primary pumps, heat exchangers and other equipment is also on the ground floor. The heat exchangers may be removed when necessary through the removable roof panels designed for this purpose.

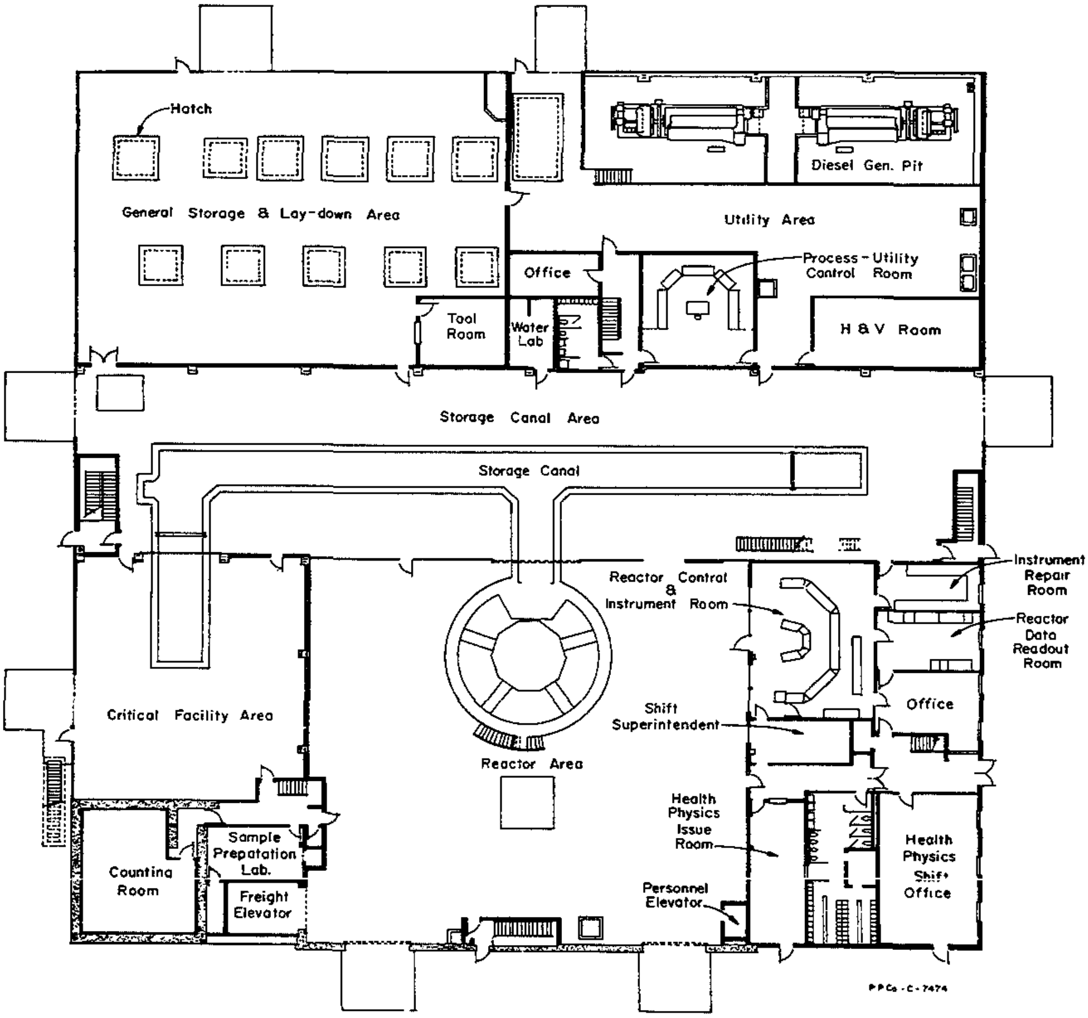


Figure 31

ATR Ground Floor Plan

The storage canal area is located between the reactor room on the south and the utility area and storage and laydown area on the north. Within the storage canal area is found the storage canal and miscellaneous heating and ventilation equipment to the east.

The southeast area of the ground floor is occupied by the reactor control room, an instrument repair room, the data processing equipment room, two offices, the health physics shift office and issue room, and a mens shower and locker room. This area is divided from the reactor room by a masonry block wall which is penetrated by several sealed windows to permit viewing the reactor from the control room.

The mezzanine floor over the areas just described contains several offices. Those offices overlooking the reactor and the reactor room have windows allowing observation of the reactor area.

West of the reactor room is the ATR critical facility, a counting room, and a laboratory. The mezzanine above houses offices and the heating and ventilating equipment.

There are two basement levels below the ground floor. The first basement (Figure 32) is 19 feet below ground and is divided into three main areas. The NE corner contains switchgear, MG sets, and battery banks. Reactor process equipment is in the NW corner. The remaining area contains the reactor, experimental cubicles, and other associated equipment.

The second basement (Figure 33) is 38 feet below the ground floor and is also divided into three main areas. The NW corner houses reactor process equipment. The NE corner houses miscellaneous services equipment and the south area contains the reactor, its access room, experimental cubicles and related equipment.

The main canal in the storage canal area is 20 feet deep, 8 feet wide, and 156 feet long. The main canal or storage canal is connected to the reactor by the working canal. The working canal contains the transfer device which allows underwater movement of radioactive material from the reactor to the storage canal. The main canal is connected to the ATR critical facility canal by an extension on the west end. All the canal sections are lined with stainless steel sheet and provision is made for insertion of inflatable seal bulkheads in several locations to isolate canal sections.

There are several cranes in the ATR building. The most important are located in the Reactor Room, above the storage canal, the critical facility, and in the utilities area.

The main exhaust stack, of concrete construction, is located north and west of the reactor building. It is 250 feet high and is connected to the main exhaust fans by underground concrete ducting.

The cooling tower and the cooling tower pumphouse are located north of the reactor building, and the main transformers are outside and east of the utilities area.

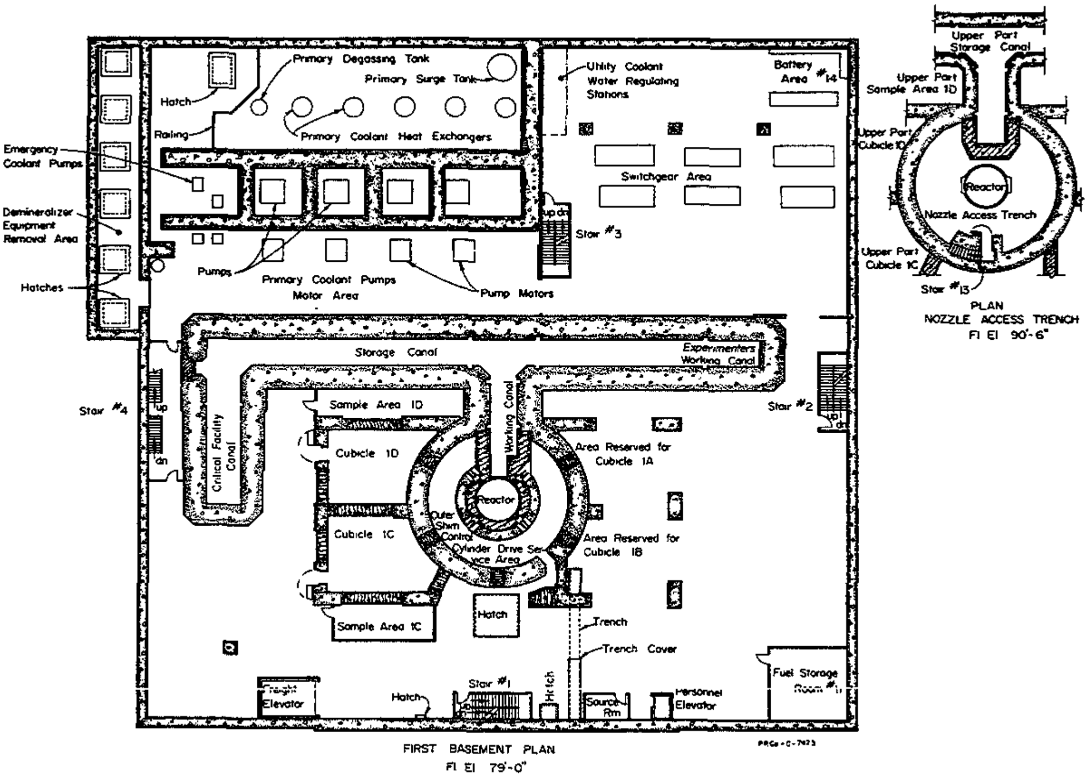


Figure 32

ATR First Basement Plan

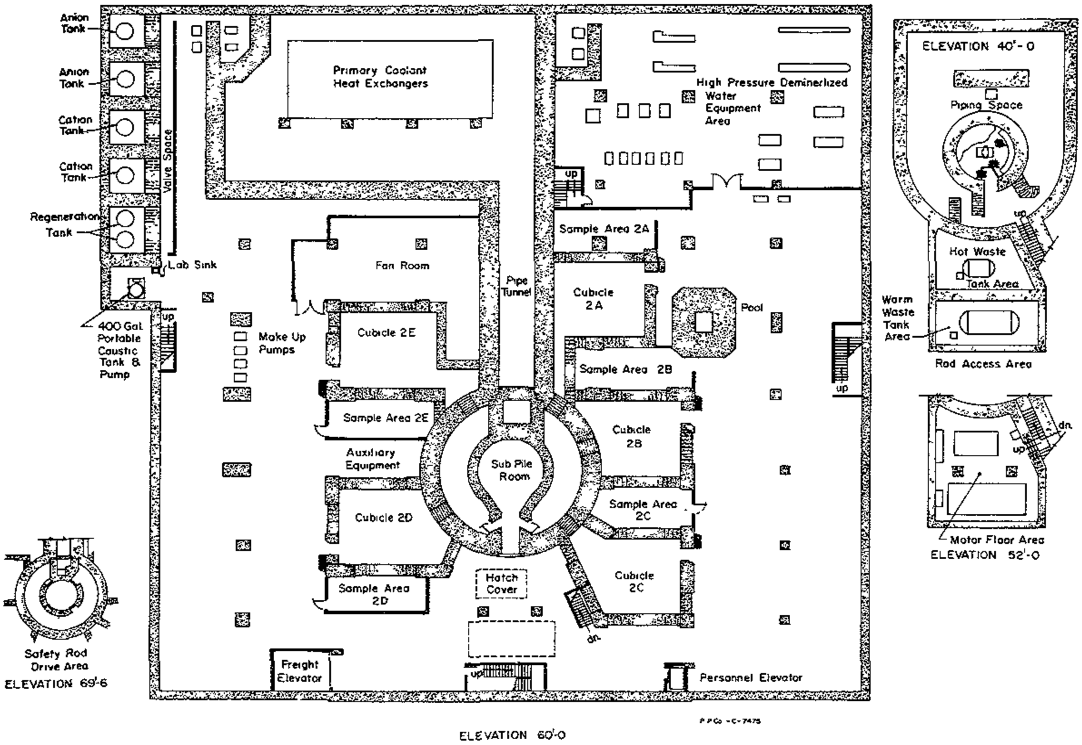


Figure 33

ATR Second Basement Plan

b. Reactor Vessel

The reactor vessel is a pressurized stainless steel tank for containing the reactor core and other internal parts. It is 35 feet in height and has an outside diameter of 12 feet. The top and bottom heads are both elliptical. Their closure plates have penetrations for in-pile loop pressure tubes. The top head has access holes which allow access to the core under normal conditions. The bottom-head closure plate also has penetrations for neck shim and regulating drive sleeves and the center flux trap baffle.

The vessel has numerous other penetrations and nozzles for control and safety rod drives, cooling water, instruments, experiment leads, etc. Its important characteristics are given in Tables II and III.

TABLE II

ATR VESSEL CHARACTERISTICS

Outside Diameter	12 ft.
Height, overall	35 ft.
Material	304 SS
Thickness	2 in. to 5 in.
Volume	3250 ft^3
Design Pressure	390 psig
Operating Pressure	355 psig inlet
Design Temperature	240°F
Operating Temperature	125°F inlet
Weight, empty	100 tons

c. Reactor Internals (See Figures 34, 35, and 36)

(1) Inlet Flow Baffle

The inlet flow baffle is a two inch thick vertical stainless steel cylindrical shell approximately 10 feet in diameter and 10 feet high. Its bottom section bolts to the flange of the core support tank.

This baffle performs two main functions, (1) it directs the cooling water from the inlets on the bottom head into the upper portion of the reactor vessel over the core, and (2) the upper portion of the baffle functions as the inner thermal shield.

Another outer thermal shield is located between the flow baffle and the vessel wall. It reduces the gamma heat to concrete shielding outside the reactor vessel.

(2) Core Support Assembly

This assembly is a stacked group of four cylindrical tank sections. It supports and contains the reactor core with the pressure vessel. It is 14.5 feet high and 50.625 inches in diameter.

TABLE III

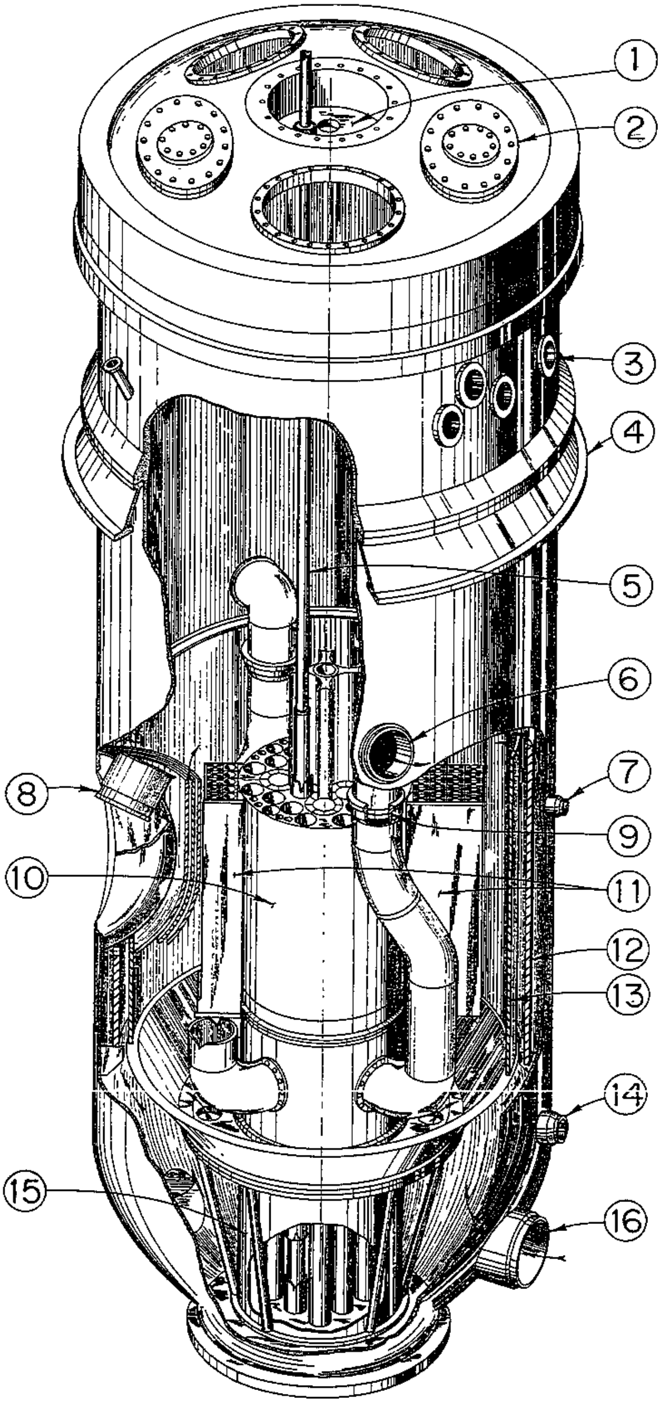
ATR VESSEL NOZZLES AND PENETRATIONS

Nozzles

Quantity	Nominal ID (inches)	Purpose	Location in Vessel
2	23	Coolant inlet	Bottom head, 12 ft. below the core
4	15	Coolant outlet	Shell course, 3.5 ft. above the core
8	6	Safety drive line	Shell course, 9.5 ft. below the core
8	3	Outer shim drive line	Shell course 1 ft. above the core
4	2	Neck shim drive line	Bottom closure plate
4	2	Demineralized water inlet	Bottom closure plate
1	8	Upper overflow	Shell course, 14.5 ft. above the core
1	8	Lower overflow	Shell course, 10 ft. above the core
12	5	Instrument thimbles	Shell course, 13 ft. above the core

Penetrations

Quantity	Nominal ID (inches)	Purpose	Method of Closure	Location in Vessel
5	20 x 40 elliptical	Refueling port	Bolted cover with gasket	Top head
5	9-3/4	Air purge port	Bolted cover with gasket	In-refueling port cover
9	6	Pressure tube penetration	Packing gland	Top closure plate
9	5-1/2	Pressure tube penetration	Packing gland	Bottom closure plate
4	12	Loop piping	Bolted cover with gasket	Shell course, 14 ft. above the core
9	10	Loop piping	Bolted cover with gasket	Shell course, 13 ft. above the core
16	3	Capsule instrument leads	Bolted cover with gasket	Shell course, 12 ft. above the core
1	16	Drop tube port	Internal cap with gasket	Blister, 1/2 ft. above the core



① Top Head Closure Plate
② Refueling Ports (5)
③ Experiment Access Flange (13)
④ Vessel Support
⑤ Experiment Pressure Tube
⑥ Coolant Outlet (4)
⑦ Shim Drive Nozzle (8)
⑧ Fuel & Experiment Drop Tube
⑨ Outlet Pipe Thermal Expansion Joint
⑩ Core Reflector Tank
⑪ Outer Reflector Experiment Facilities
⑫ Thermal Shield
⑬ Inlet Flow Baffel
⑭ Safety Rod Drive Nozzle (8)
⑮ Core Support Tank
⑯ Coolant Inlet (4)

Figure 34

ATR Vessel Assembly

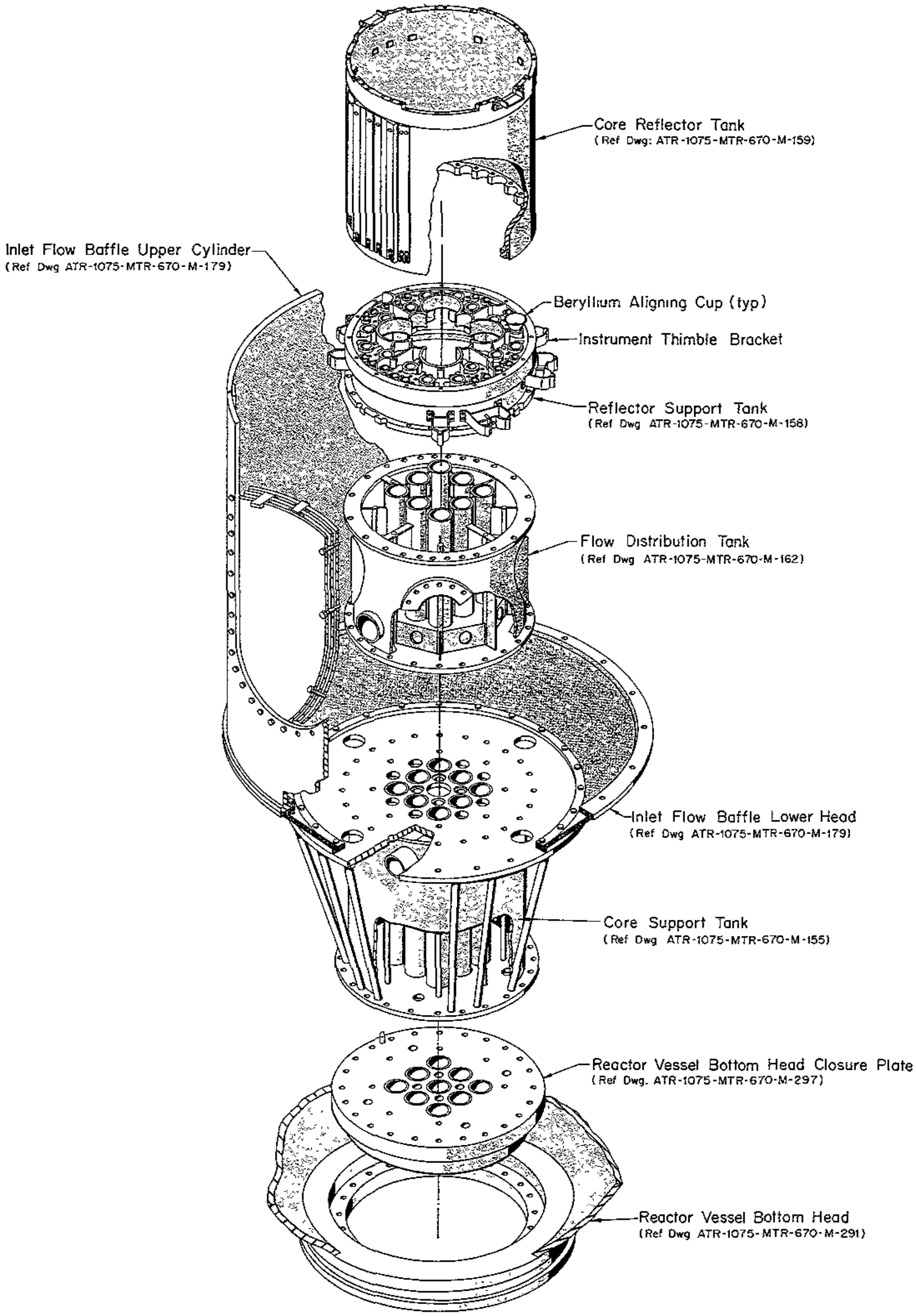


Figure 35

ATR Internal Tank Assembly

① BERYLLIUM REFLECTOR BLOCK
② PRESSURE TUBE ASSEMBLY
③ FUEL ELEMENT
④ OUTER SHIM DRIVE SHAFT
⑤ REACTOR VESSEL
⑥ THERMAL SHIELD
⑦ INSTRUMENT THIMBLE
⑧ NECK SHIM ROD HOUSING
⑨ INNER CAPSULE IRRADIATION FACILITY
⑩ PRESSURE TUBE LOCATOR TIES
⑪ OUTER SHIM GEAR BOX
⑫ OUTLET FLOW PIPE
⑬ OUTER FLUX TRAP BAFFLE
HOLD DOWN LATCH
⑭ FUEL STORAGE RACK
⑮ CORE REFLECTOR TANK
⑯ OUTER SHIM CONTROL CYLINDER
⑰ INLET FLOW BAFFLE ASSEMBLY
⑱ N-16 SAMPLE TUBE
⑲ GEAR BOX SUPPORT BEAM
⑳ OUTER CAPSULE IRRADIATION FACILITY
㉑ SAFETY ROD
㉒ DROP TUBE
㉓ REFUELING PORT RP-1
㉔ REFUELING PORT RP-2
㉕ REFUELING PORT RP-3
㉖ REFUELING PORT RP-4
㉗ REFUELING PORT RP-5

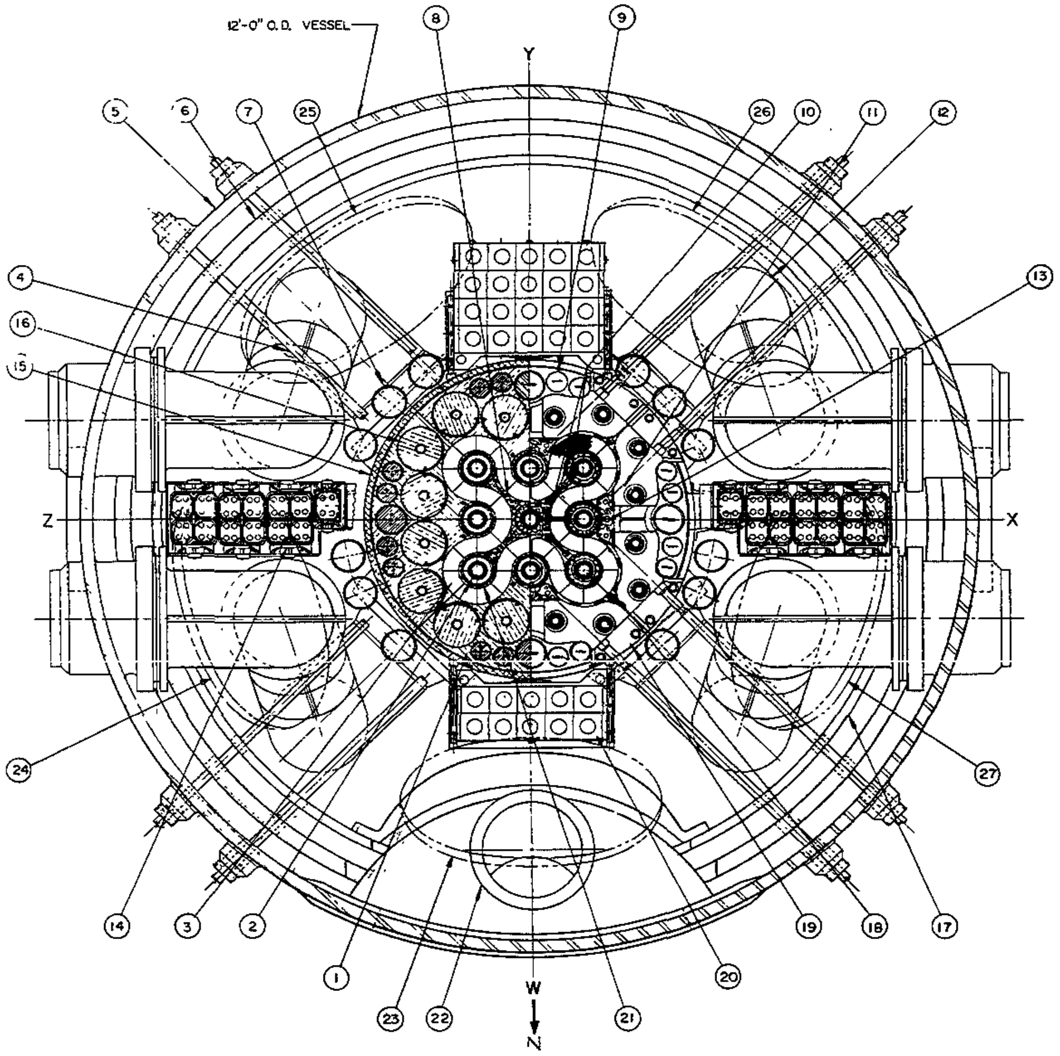


Figure 36

ATR Vessel Internals Plan

(a) Core Support Tank

This is the lowest tank in the assembly and is 61.5 inches high. Its lower flange bolts to the bottom head closure plate. It is primarily a supporting structure, although it does contain sleeves for safety rods and N_{16} monitor tubes, as well as flanges for emergency fire-water inlets and outlets and neck shim drive housings.

(b) Flow Distribution Tank

This tank, 39.5 inches high, is bolted to the top of the tank mentioned above. It is a critical component in the alignment of the entire core assembly. It is open at the top but closed at the bottom by the core support plate. This core support plate locates and supports major core components including safety rod guide tubes and flux trap baffles, the center flux trap baffle, and the neck shim rod housing.

The upper portion of the flow distribution tank is divided by four vertical baffles which split total reactor core flow from the four quadrants and direct flow to each of the four internal outlet pipes. A plenum in the lower one foot of the tank collects flow from the flux trap baffles and most of the aluminum capsule facilities and distributes it equally to the four quadrants.

(c) Reflector Support Tank

This tank, although only one foot high, is very complex in design and fabricated from aluminum casting. It is of extreme importance in locating the beryllium control cylinders and locating and supporting reflector filler blocks. Its lower flange bolts to the flow distribution tank and its upper flange, in addition to bolting to the highest tank in the assembly, projects inwardly to form a flat ring support assembly.

The penetrations receive funnel shaped alignment cups for the reflector blocks and the outer cylinders, as well as providing positioning bushings for a capsule can that will be placed in the reflector irradiation facilities.

(d) Core Reflector Tank

The last, or highest, tank in the stack of four is made of aluminum and is 58.25 inches high and open at top and bottom (Figure 35). It bolts to the reflector support tank and contains the fuel-reflector core assembly. It helps to support the beryllium reflector blocks by means of a small internal bottom flange. Its top supports the gear box beams for the cylinder drives. The top of this tank projects 4 inches above the top of the final core to keep the core covered with the water at all times.

(3) Outlet Flow Pipe

Four 16-inch-OD SS outlet flow pipes connect the four quadrants of the flow distribution tank to the reactor vessel outlet nozzles (Figure 34). Each flow pipe is equipped with a sliding piston ring type expansion joint. One inch equalizing lines run from the top of each flow pipe to a location just under the vessel head, serving as siphon breakers.

(4) Reactor Core Assembly

(a) General Description

The core is the heart of the ATR. In its 4-foot high by 50-9/16 inch diameter volume is contained the fuel, beryllium reflector, safety rods, neck shim and regulating rods, outer cylinder shims, and the sections of in-pile pressure tubes occupied by loop experiments. It is built of carefully fitted parts and its geometry is set by the neck shim rod housing, the flux trap baffles, and the core-reflector tank (see Figure 37).

(b) Neck Shim Housing

This is the central structural member of the core. It helps define the dimensions of the serpentine fuel annulus. It also contains holes to accommodate neck shim and regulating rods, the center flux trap baffle, and small radiation surveillance specimens.

(c) Center Flux Trap Baffle

This is a long aluminum tube which passes through the center of the neck shim housing, the core support plate, and the reactor bottom head. Its function is to receive filler pieces and contain some of the nitrogen-16 sample assemblies.

(d) Inner and Outer Flux Trap Baffles

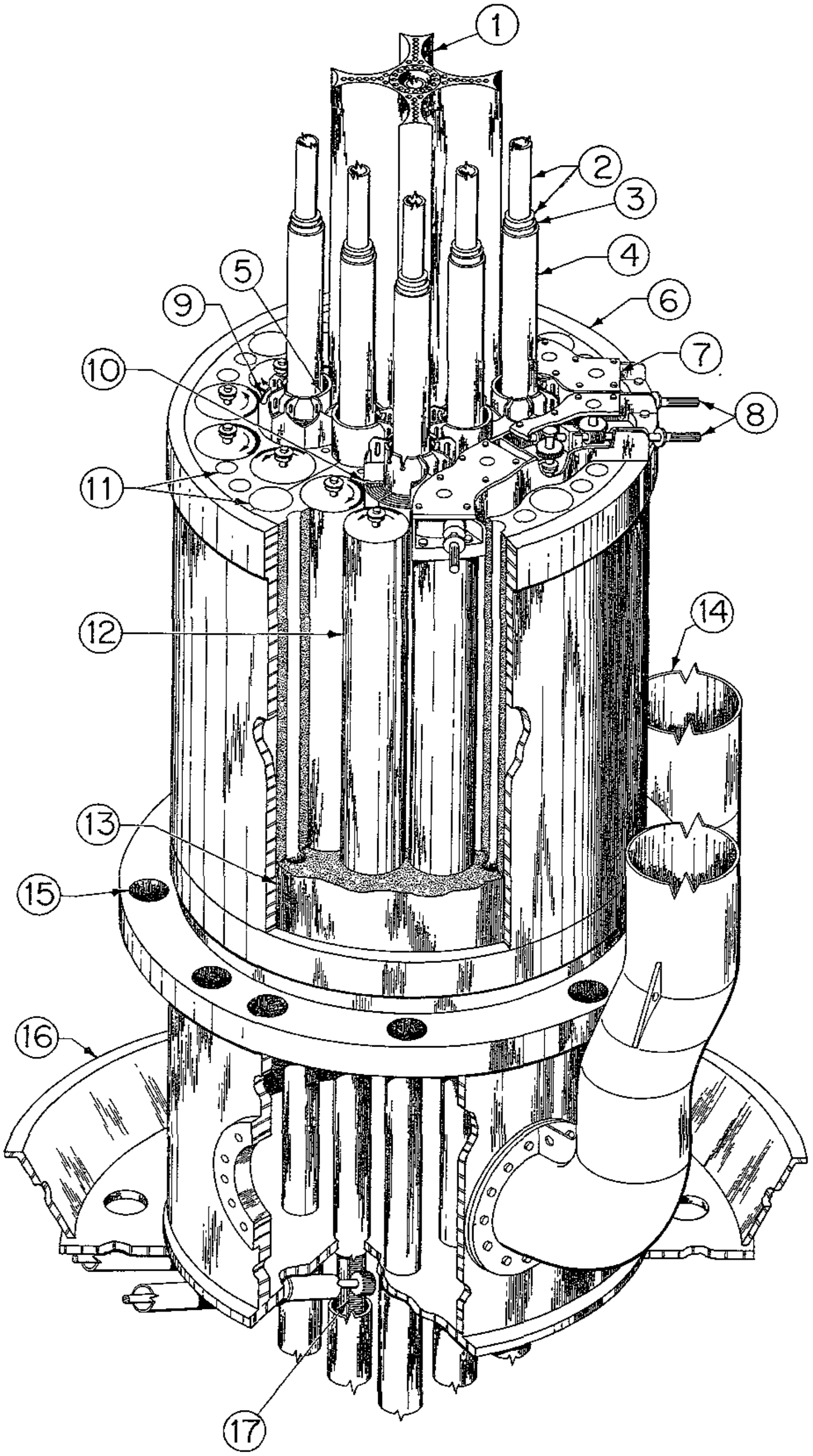
These eight vertical tubes, 5-7/8 inch OD by 5-1/4 inch ID, support and locate the fuel elements and provide the boundary for the flux traps in which are installed the in-pile experiment pressure tubes and, in specified locations, the safety rods. They are seated inside support tubes mounted on the core support plate and extend upward to a point approximately 17 inches above the core's actual fuel region. All eight baffles are slotted at the top and have a slotted-top flange near the bottom to receive and support the fuel elements (Figure 37).

(e) Beryllium Reflector

The reactor core is completed by 16 movable beryllium control cylinders, 8 fixed beryllium core reflector blocks, and the fuel elements. The fixed reflector blocks are supported at the bottom by the reflector support tank and positioned laterally at the top by the outer shim cylinder gear box support beams by means of alignment cups.

(5) Gearbox Support Beams

These beams support portions of the outer cylinder drive mechanisms and the outer flux trap baffles, and are, therefore, important in core alignment.



① Neck Shim Housing
② Experiment Pressure Tube And Outer Shell
③ Safety Rod
④ Safety Rod Housing
⑤ Flux Trap Baffle
⑥ Core-Reflector Tank
⑦ Outer Shim Gear Box
⑧ Outer Shim Drives
⑨ Fuel Element End Box
⑩ Fuel Plates
⑪ Beryllium Experiment Facilities
⑫ Outer Shim Drum
⑬ Beryllium Reflector
⑭ Outlet Coolant Pipe (1 of 4)
⑮ Nuclear Instrument Thimble Support
⑯ Inlet Coolant Flow Baffle
⑰ Safety Rod Rack And Pinion Drive

Figure 37

ATR Core Reflector Assembly

(6) Fuel Elements

The ATR serpentine fuel annulus requires a circular sector fuel element. Each element consists of 19 parallel curved fuel plates attached to two side plates to form a 45 degree sector of a right circular cylinder (see Figure 38). Forty of these elements complete the core loadings.

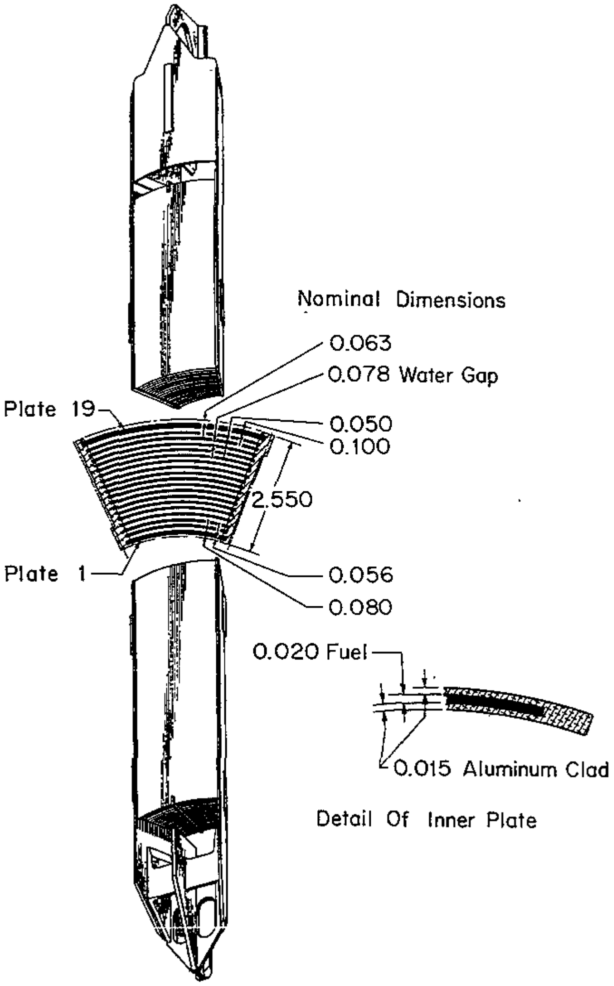


Figure 38

ATR Fuel Element Assembly and Details

Each fuel plate has an active fueled length of 48 inches. Plate thickness is varied at the two outermost plates to withstand large pressure differentials at these two locations. Side plates are slotted at intervals to reduce lateral pressure differentials.

The element end fittings are designed for supporting and positioning the fuel element on the flux trap baffles. The upper fittings also provide a lifting handle to permit handling into and out of the core.

d. Control and Safety Rods and Drive System

(1) General

The ATR is equipped with three separate systems of movable control: the safety rods and drives, the neck shim rods and drives (including two rods and drives used for fine servo control), and the outer shim cylinders and drives. Nuclear characteristics of the control rods are given later. This section pertains to the mechanics of their design, installation, and operation.

(2) Outer Cylinder Shims and Drives

The outer shim control element is a beryllium cylinder 7-1/4 inches in diameter and 46-13/16 inches long which has hafnium poison plate sections covering 120 degrees of its surface. Sixteen such cylinders, arranged in eight pairs, are fitted into the fixed beryllium reflector blocks.

The hafnium in the cylinder is in the form of six replaceable inserts and the drum is drilled with multiple vertical holes to allow flow of cooling water.

Each drum has aluminum end plates and an aluminum shaft through its center. The upper end plate is bolted to a connector column at the bottom of the internal drive gearbox. The lower end "floats" but will drop into a smooth bearing surface should the upper connection fail. The construction prevents the drum from turning in a more reactive direction in the event of connector failure.

Each pair of cylinders is driven by one outer shim drive mechanism consisting of an internal worm gearbox, a horizontal drive shaft, a shaft housing assembly, and an external motor drive assembly. The horizontal shafts are equipped with water flushed mechanical seals.

(3) Neck Shim and Regulating Rods and Drives

Both the neck shims and the regulating rods are fluted hafnium rods drilled with a center hole for passage of cooling water.

Of the 24 locations in the neck shim housing, 22 are occupied by shim rods and 2 by regulating rods. It is possible to convert 2 additional rods to regulating rod service if necessary. All of the neck shim housing holes are provided with liners (aluminum). The neck shim rods operate within aluminum guide tubes and the regulating rods have similar Iconel guide tubes. These guide tubes pass through the reactor bottom head and extend into the neck shim rod access room, which contains the drive motors and mechanisms.

The 22 neck shim rods are driven by Teleflex cables which are, in essence, flexible jack screws driven by a small electric motor through a worm gear. These drive cables do not rotate, but exert a push-pull motion within guide tubes which prevent them from buckling in compression.

The regulating rods are connected to their drive motor by a straight through, rigid Iconel drive rod. These rods operate through a labyrinth seal at the reactor bottom head, whereas the shim rod cable guide tube and worm gear housing are under direct reactor operating pressure. The drive motor for the regulating rods is larger than those supplied for the neck shims and is under servo control.

(4) Safety Rods and Drives

The ATR safety rod is a vertically moving tubular assembly which operates within the annulus formed by the outer surface of the loop pressure tube insulation can and the inner surface of the flux trap baffle. The assembly is composed of an aluminum guide tube, 9 feet long, which is the structural member that guides and supports the:

(a) Poison inserts, which are four 80 degree sections of hafnium 36 inches long and 1/4 inch thick, and are latched to the upper section of the guide tube.

(b) Flux trap fillers, which are aluminum inserts installed in guide tube slots directly below the poison inserts.

(c) Flux wire assemblies, which are inserted in small holes in the guide tube walls and which serve as lock pins in the poison plate latching assembly.

Connected to the bottom of the guide tube is a drive tube assembly driven by a rack and pinion linkage to an electric motor drive located outside the reactor vessel. A hydraulic snubber is provided below the rack tube to decelerate the safety rod assembly as it nears the end of its travel following a scram.

Five safety rods and drives are provided in five different flux trap locations.

The safety rod drive is comprised of a drive motor; gearbox; electro-magnetic clutch; accelerating spring assembly, which is coupled to the horizontal drive shaft through a ball screw assembly; the horizontal drive shaft, which passes through a nozzle in the vessel wall equipped with a mechanical face seal and which is supported internally by a water cooled bearing supported in the core support tank, and the rack and pinion gear set.

e. Instrument Thimbles and Chamber Drives

Immediately outside the core-reflector tank are located twelve instrument thimbles. Ten thimbles extend to the bottom of the reflector support tank and are clamped to the wall of this tank. Two thimbles are shorter, ending about 1-1/2 feet above the core and are clamped to adjoining thimbles. One of these two short thimbles accommodates the control system galvanometer ion chamber, the other is a spare. The ten long thimbles contain ion chambers for the neutron level, start level, servo, and Log-N Period channels.

All of the thimbles are equipped for dry gas purging and contain a stainless steel and polyethylene shield plug to prevent radiation streaming.

The ion chambers are mounted on wheeled carriages which are moved into and out of the thimbles by means of an aluminum support-coaxial transmission cable fabricated as a unit. This cable is wound onto drums in the nozzle trench as chambers are raised. Drums for the fission chamber cables are motor driven, and provision has been made to convert all drums to motor drives.

f. Experimental Facilities

(1) Pressure Tube Facilities

ATR was designed primarily to accommodate dynamic or loop type experiments in high flux positions. Details of design, fabrication, and operation of loop experiments will be found elsewhere. This section pertains only to provisions made to receive the in-tank or in-pile hardware.

Each of the nine flux trap positions is designed to receive an in-pile pressure tube. The alignment of penetrations in the top and bottom-head closure plates and the centers of the circles circumscribed by the flux trap baffles have been set with a high degree of precision. Pressure tubes installed in these nine locations will penetrate both heads through O-ring or packed seals. Inlet and outlet lines are located in the subpile room. In five of the nine locations the in-pile tubes will be surrounded by safety rods assemblies. In in-pile tube locations where safety rods are not installed, a dummy flux trap filler must be installed to restrict water flow. In flux traps containing neither in-pile tubes nor safety rods, a dummy in-pile tube as well as a dummy flux trap filler are installed.

In addition to the high flux lobe positions other facilities which might be used for loop experiments have been provided by penetrations in the beryllium reflector blocks. Four 5-inch-diameter and sixteen 3.25-inch-diameter holes of this nature have been provided.

(2) Capsule Facilities

The penetrations in the beryllium reflector, although potentially usable for specially designed loop experiments, were provided primarily for irradiation of capsule type experiments, either instrumented or uninstrumented. When not in use, the holes will be plugged with removable beryllium filler pieces.

Additional irradiation facilities are provided outside the core reflector tank by means of capsule irradiation "tanks" attached to the outside of the core reflector tank. The north tank is comprised of a 2 x 5 array of irradiation positions; the south tank is a 4 x 5 array. These positions are occupied by aluminum filler pieces drilled to accommodate capsules of various sizes.

g. Vessel Accessories

(1) Drop Tube

Radioactive material, including spent fuel, is discharged from the reactor vessel through a penetration in the wall to the working canal through a drop tube. The vessel penetration is 16 inches in diameter and is located in a "blister" which provides the approach angle necessary to discharge relatively large items such as fuel elements. During operation this penetration is closed with the drop tube cover.

A discharge mechanism in the working canal, which is an aluminum tube pivoted at its lower end, mates at its upper end with the vessel drop tube penetration. This tube receives inserts at its upper end which contain material being discharged. The tube, after loading, is pivoted with a hydraulic piston to a vertical position in the canal for removal of the discharged material.

(2) Internal Fuel Storage Racks

Two fuel storage racks, each with a 12 element capacity, are located inside the reactor vessel for interim storage of fuel elements. The racks will accommodate either fresh or irradiated fuel during an operating cycle. Coolant flow through the fuel is by natural thermal circulation since the rack frames are stainless steel plate boxes, open at the top end only. A poison insert consisting of an aluminum clad cadmium plate must be inserted in each fuel basket before fuel may be stored.

(3) Protective Covers

A horizontal plane in the annulus between the core-reflector tank and the reactor vessel is covered by stainless steel expanded metal screen and segmented aluminum cover plates to keep foreign objects inadvertently dropped from sinking to the bottom and being lost. The aluminum plate covers are provided with six hinged six-inch "flow hats" to permit limited water flow and access below without removing entire cover plate sections.

(4) Internal Support Bars

Twenty-three vertical slotted 4" x 4" "T" bars are welded to the vessel wall to provide anchor points for clamps which will be required to support pressure tubes and lead experiments.

B. Brief Description of an ATR Shutdown

1. Introduction

The ATR will normally operate on a three-week cycle which consists of four days of shutdown and seventeen days of operation. Because a great deal of work must be done during shutdown, it is necessary that it be coordinated so as to afford maximum efficiency in job completion. The TRA maintenance department is presently using the "critical path" method of job and manpower scheduling. This method, utilizing computer programs, permits prediction of shutdown length, craft requirements at any time during shutdown, and what job schedule will lead to minimum reactor downtime.

Maintenance, Plant Engineering, and Project Engineering Branches are required to formulate and submit the shutdown jobs to be performed to TRA Planning and Scheduling Branch at least one week before the published shutdown date.

2. Reactor Preparation

As far as Operations is concerned, shutdown preparations will also start during the week before actual shutdown. All reactor and hand tools to be used during a shutdown must be checked for operation and all damaged or broken tools repaired or replaced. This tool check will include underwater lights and in-tank sight glasses. During the eight hours immediately preceeding shutdown, most experimenters require special pre-shutdown tests of samples. These special items must be completed before the normal shutdown time of 1200, Sunday.

Scheduled reactor shutdowns afford the opportunity of live-checking the reactor safety circuitry. Each reactor and process instrument or circuit that can originate a reactor power reduction will be live-checked periodically. The process water operators will start a two-hour degassing period followed by a one-hour demineralized water flush after the reactor is locked out and the key returned to the shift supervisor. These procedures are necessary to reduce the activity levels in the primary coolant system before the top head is opened. During this three-hour period, the reactor engineers will suit up for tank work and assist the health physicist in preparing the reactor top monitors and setting up the contamination control ribboned areas. The reactor top neutron count rate meter (CRM) must also be checked for proper operations and alarms. The process operator will inform the shift supervisor when the degas-flush period is completed and the reactor tank work may proceed.

3. Routine Tank Operations

The five top-head shielding blocks are run back using the pneumatic wrench and the reactor upper drain and vent opened. When the reactor top warm waste tank level indicator shows no further increase, two adjacent refueling port covers are removed using the impact wrench and 2-ton crane. The vent duct gates for these two ports should be opened and the vent ducts and adapters installed to purge the top dome of radioactive gases. Another refueling port cover should then be removed to aid the purge. When any of these covers are removed, constant health physics monitoring is required and the health physicist in attendance will approve the removal of the remaining port covers. When he gives approval, one of the vent duct gates may be closed, its vent duct removed, and the refueling port seal protective covers installed in four positions. The fifth position must always be connected to the vent system to prevent the spread of airborne contamination from the reactor tank.

The next step is to install the in-tank lights and make an initial tank inspection. The drop tube cover is removed using the wrench tool and large safety hook tool and stored on the in-tank storage bracket. The outer pressure tube locator ties are unlatched and removed to provide access to the fuel elements around the outer flux trap baffles. A quantity of fuel, the specific positions as listed in the reactor shutdown schedule, must be removed to the in-tank storage racks and replaced with dummy filler pieces to ensure nuclear safety during shutdown operations. To reduce coolant flow channeling, only one element or filler should be out of the core at a time. When the dummy fillers are in place, a flux wire bucket will be transferred to the tank from the canal and the full cycle flux monitors discharged. The wires must be handled using a safety latch hook tool so none will be dropped and lost. After all full cycle flux monitors are removed and the full bucket transferred to the canal, the capsule experiments in the tank are discharged. The capsule experiments and baskets are also handled with the safety latch hook tool.

The reactor shutdown is scheduled so that the Naval Reactor (NR) experiment removals will start about 0800 Monday morning. The preparation of these experiments should begin about 0400 Monday which, due to the reactor design, will not interfere with Operation's tank work. The detailed procedures for preparing an experiment for removal are found in the loop operating manual. Briefly, the procedure requires depressurizing the loop, removing the transfer plate shield plug and connector plug retainer, and unplugging the specimen thermocouples. The closure plug locking ring is then unscrewed with the lock ring tool and the assembly lifted about two inches and rotated 90° to make sure it is free in the tube. The transfer sleeve O-ring on the in-pile tube should be checked for damage, after which the specimen thermocouples should be reconnected until the sample is removed. The transfer plate shield plug should be carefully reinserted so it does not rest on top of the lifting adapter. Actual sample removal involves use of the NR cask to transfer the samples from the in-pile tube to the canal. When a sample is ready to be discharged, its specimen thermocouples are disconnected and the transfer sleeve inserted around the lifting adapter and filled with demineralized water. The NR cask is lowered over the proper hole on the transfer plate and the bayonet adapter on the cask winch locked to the sample's lifting adapter. The cask is then filled with demineralized water and the sample lifted into the cask. When a sample is either discharged from or inserted into an in-pile tube, all five top-head shielding doors must be closed to reduce the main floor radiation levels. With the sample fully in the cask, as determined by a health physics survey, the cask lower door is closed and the cask moved to the sample transfer station. At this station, the sample is lowered into the canal for later transfer to the experimenter's water pits or to the experiment facility at the east end of the ATR canal. In-pile sample removal will occupy the reactor tank until sometime Monday evening.

The next tank job will be the removal and replacement of the flux wires in the safety rods. The wire holders are unscrewed and discharged using a special flux wire handling tool which incorporates a socket and positive latch to firmly hold the monitor during removal. After the four monitor holders are removed from a safety rod, the poison plates or flux trap fillers may be changed. Only one rod may be serviced at a time since this operation involves temporarily removing a considerable amount of nuclear poison from the core.

Once work is completed on the safety rods, the drop tube cover will be replaced and the reactor water level lowered to the lower drain (elevation 92 feet 4 inches) to prepare the reactor tank for lead insertion and removal. Since these lead experiments are usually quite fragile and most will be ruined if reactor water is allowed into the instrument tube, great care must be taken during all lead handling. The leads incorporate an in-tank connector to facilitate this handling. In order to remove a lead, it will be unclamped, the in-tank connector undone, and the top section removed. This work requires a man in-tank on a bosun's chair; hence, constant health physics surveillance is required. After the nozzle penetration is plugged, the lead is lifted as high as radiation fields allow, the lead tube cut, and a water-tight cap installed. When all leads to be removed are cut and capped and the empty nozzle penetrations plugged, the reactor water level may be raised and the leads discharged to the canal. The drop tube cover must be reinstalled and the water level lowered to install a lead experiment. The lower section is carefully set into place while precautions are taken so that the instrument leads are not damaged. The top section is then inserted in the proper nozzle penetration, the instrumentation leads pulled through to the nozzle trench, and the in-tank connector made up. A pressure test will then be run on the connector to detect a faulty seal that could allow reactor water into the tube. If the seals are tight, the lead can be clamped, the nozzle penetration sealed, and the reactor water level returned to normal.

After lead experiment insertions and removals are complete, any work to be done on the neck shim rods or outer shim cylinders may proceed. The inner pressure tube ties must be unlatched from around the pressure tubes and swung out of the way to gain access to the neck shim rods and sleeves.

The reactor may not be refueled until all shim and safety rod work has been completed. This is to take advantage of the poisons in the used fuel for additional shutdown margin. The refueling will normally be with new elements unless a mid-cycle shutdown is contemplated; in which case, a partially burned core from the canal may be installed. During refueling, constant health physics monitoring is required since the fuel must be lifted to within 12 feet of the reactor surface to clear the drop tube. The reactor top CRM must be carefully observed to warn of an inadvertent criticality. The dummy filler piece positions will not be refueled until after all in-pile tube samples are reinstalled.

The reactor is now being prepared for the next cycle start-up; therefore, the capsules and flux monitors (FM) to be irradiated must be installed. Capsule and flow restrictor insertion should be completed before any flux monitors are installed so that dropped FM will not go through the core. After these items are installed, the reactor core and reflector positions must be inventoried. This inventory involves accounting for each position in the reactor and determining its contents and experiment depth measurement in each facility in use. The inventory is one of the most important shutdown jobs as the consequences of a missing experiment or misplaced experiment can be very severe. If a lead experiment inventory is incorrect, it must be unclamped and reseated or completely removed and spacer lengths checked. In the case of an incorrect capsule inventory, the basket should be discharged to the canal and the basket loading rechecked. Any extraneous material in the reactor tank should also be noted and removed if at all possible.

All the preceding reactor tank work should be completed by Friday morning of shutdown week so that the in-pile tube samples may be reinstalled. The installation is essentially the reverse of the removal procedures. The samples will have been unloaded to the canal and moved to the test assembly storage rack in the reactor building proper. They are then moved one by one to the cask transfer station, loaded into the NR cask, and reinserted wet into the appropriate tube. Precise location records must be kept since the five NR and one Division of Reactor Development (DRD) samples are physically interchangeable and any mixup would have serious results. At best, the shutdown would be delayed while the discrepancies were resolved; and at worst, a sample meltdown could occur. After all in-pile tube samples have been inserted and pressure tested, the eight dummy filler pieces may be removed and these positions refueled. The pressure tube locator ties will also be reinstalled.

The reactor is now essentially ready to start-up as fuel is installed and all samples and flux monitors are in. The Operation's shutdown work now consists of checking and cross-checking to make sure all reactor components are installed properly and no loose items are left in-tank. The core and upper portions of the tank are meticulously inspected and all foreign matter removed. The reactor top tool and equipment pinboard is checked, and all missing items located. It is a firm axiom that the reactor will never be sealed for start-up without all pinboard items accounted for. The time spent in this checking is small compared to the consequences of a fuel element flow blockage with the reactor at power. Only when the shift supervisor on duty is satisfied that the reactor "sponge count" is correct will the drop tube cover be seated and bolted down and the in-tank lights removed. The refueling port covers are then reinstalled and bolted down after which the vent duct gates may be closed. The reactor engineer on the reactor top will run a hose from the reactor top vent to the canal, close the upper drain, and request that the process operator fill the reactor tank. When the tank is thoroughly vented, the vent is closed and the refueling port covers checked for leakage. The shielding doors are not rolled in until the port covers have been leak checked at full primary system pressure.

4. Nonroutine Tank Operations

All nonroutine tank operations are covered by detailed procedures and these procedures should be followed closely. Such nonroutine jobs would include inpile tube replacement, rod drive replacement, beryllium block changeout, and other items which require major component dismantling. All in-tank components except the core support assembly are removable and it is conceivable that they will eventually be removed.

A second phase of nonroutine tank work is the operation of the reactor for flux runs and gamma heat runs. These special reactor measurements are necessary to obtain correlations between the ATR and ATRC. A flux run requires the insertion of possibly 100 special flux wires in the reflector and neck shim regions. The accountability of these wires is vital since they are not designed for full-power, full-flow conditions. The gamma heating in the reactor is measured by small diameter gamma chambers which are inserted into dry aluminum tubes in the reflector region. Chambers will be moved to various positions to get a radial and axial gamma scan of the reactor. Both gamma and flux runs are carried out under open-head conditions at power levels of 2 megawatts or less.

5. Nontank Operations

The rest of the reactor plant and equipment has been far from idle during a shutdown. Very few pieces of equipment in the building are available for maintenance or inspection while the reactor is operating, due to high radiation fields or interconnections with the reactor control circuitry.

In the nonnuclear portion of the reactor, equipment will be inspected, tested, and sometimes modified or replaced as conditions dictate. A testing reactor is continually in a state of change as experiments and experimental programs are started, modified, or discontinued. Piping must be installed or rerouted, electrical services installed, and other utility systems modified as the experiment load fluctuates. Some of this work can be done with the reactor operating, but most tie-ins to existing systems have to be done during shutdown. These jobs must be accomplished in addition to the base plant modifications for improvement of reactor operation or safety.

Work on the experimental piping, equipment, or instrumentation is almost entirely limited to shutdown periods. The experimental loops are designed to operate the test specimens at their limits so almost no experimental equipment can safely be taken out of service with the reactor operating. The node diagram illustrates typical loop shutdown jobs such as ion exchange resin changeout, hot crud filter changeout, and wiring modifications. In addition to the maintenance jobs, about 300 instrument setpoints require checking and resetting each shutdown.

C. Cooling and Water Systems

1. Primary Coolant Systems

a. System Description

The ATR primary coolant system includes facilities for reactor heat removal, reduction of radioactivity in the reactor coolant, sealing water for pumps and reactor vessel penetrations, and reactor cooling water pH control.

The primary coolant system is a light water, medium pressure, low temperature, forced flow, closed loop constructed principally of stainless steel. Heat absorbed by the coolant flowing through the reactor core is transferred to the secondary coolant system in heat exchangers and dissipated to the atmosphere via the cooling tower. A simplified sketch of the reactor coolant flow path is shown in Figure 39.

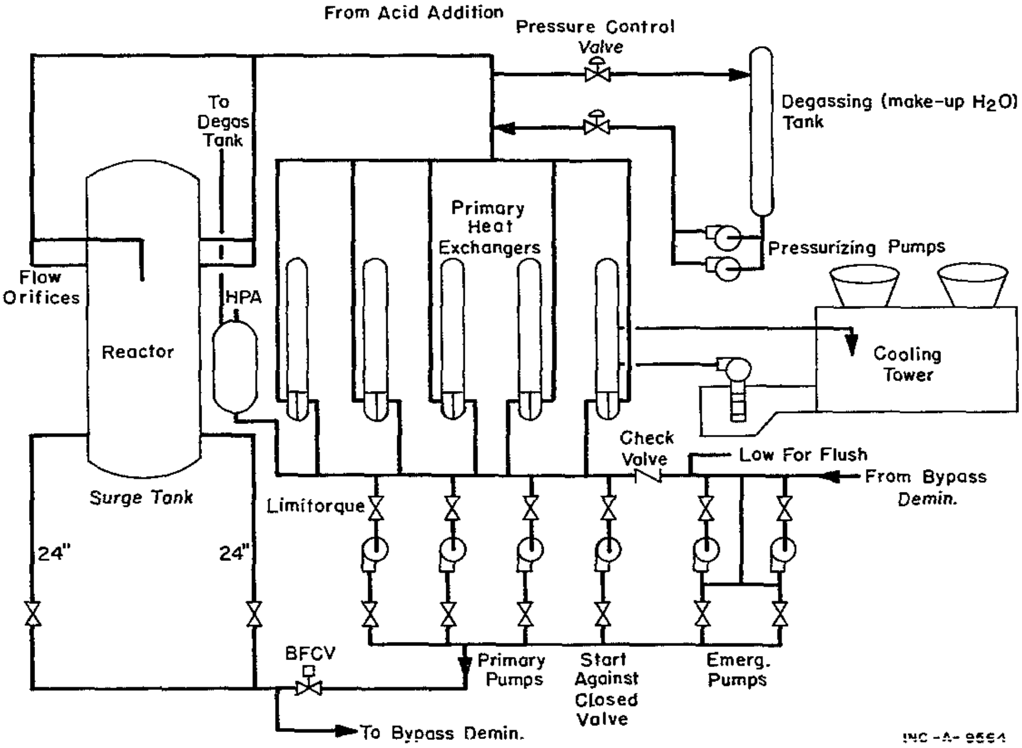


Figure 39

ATR Simplified Primary Coolant System

The coolant is circulated by three primary pumps, and a fourth is maintained as a standby unit. The pumps discharge into a common 36-inch reactor supply line, through a remote operated flow control valve, and into two 24-inch reactor vessel inlet lines entering near the bottom of the vessel.

Coolant flows upward outside of the core reflector tank with approximately 95 percent directed around the thermal shield between the inlet flow baffle and the vessel wall. The remainder passes upward between the reflector tank and the flow baffle. Above the core, flow reverses to a downward direction, through the core area into the flow distribution tank (see Figure 40).

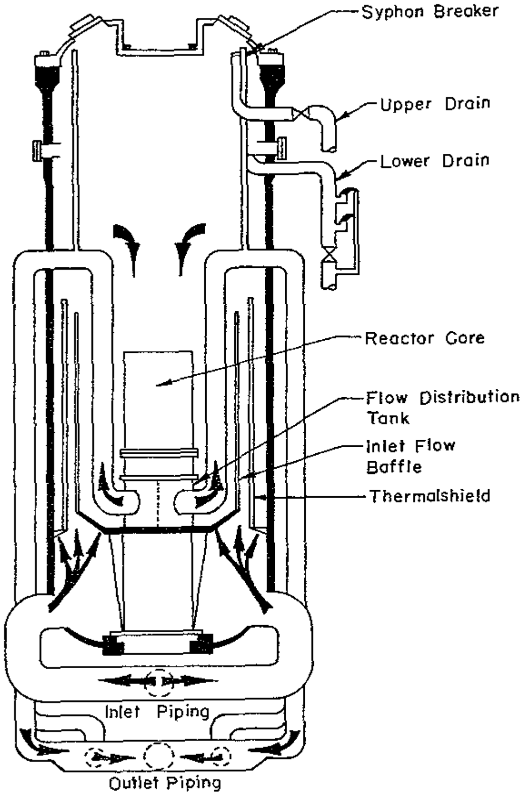


Figure 40

ATR Vessel Coolant Flow Path

The distribution tank is divided into four quadrants with an outlet line from each quadrant. The four outlets rise to above the core, exit from the vessel, and terminate into one 36-inch return line in the rod access corridor. Each outlet line is instrumented to measure flow and temperature rise to determine the portion of reactor power produced in each quadrant.

Reactor outlet coolant passes through five heat exchangers, having common supply and discharge headers, to the pump suction. Coolant temperature is controlled by varying the secondary flow through the heat exchangers.

System pressure is maintained by pumping a constant volume of makeup water into the circulating stream from a degassing tank and bleeding a varying amount back into the degassing tank. Excess gases are removed by an air stream drawn through the degassing tank.

A surge tank is connected to the pump suction header and serves to dampen rapid pressure transients. The tank contains 95 percent water and 5 percent air when the system is operating at normal pressure and flow.

Two emergency pumps are provided, one normally operating to ensure that the reactor will be adequately cooled during shutdown, flux runs, and upon failure of the main circulating pumps. One pump is driven by an ac motor that may be powered by either commercial or diesel power. The other pump is driven by a dc motor and battery bank, and will continue to operate if both commercial and diesel power are lost.

An 8-inch fire-water line is connected to the reactor vessel by four 2-inch lines through the bottom closure. Two self-operated valves in the 8-inch supply line are closed when the vessel water level is above the four outlet lines. Should the vessel level fall to the outlet lines, approximately four feet above the core, these valves open to supply sufficient water to ensure that the fuel elements remain covered.

In order to maintain the reactor coolant free from impurities and to remove fission products following a fission break, a small side stream is circulated through the bypass demineralizer system. The bypass demineralizer consists of two cation beds and two anion beds piped to provide flow through any combination of units. Provisions are incorporated for regeneration of the anion units and for disposal of the cation resin.

The gland seal system provides a source of water for pump and vessel penetration seals, purging, and N-16 monitoring. Two sources of supply and uses are provided: (a) fresh demineralized water, and (b) reactor coolant drawn from the circulating stream. In general, fresh water is used where leakage to the reactor building atmosphere may release radioactivity, and reactor coolant is used for purging where external leakage is not expected. The two subsystems are known as primary seal water and warm seal water.

Primary seal water is supplied and distributed by two pumps, one normally operating. To ensure that seal leakage will be seal water rather than contaminated primary water, the seal water is regulated to different pressures dependent upon the usage. Seal water is supplied to several distribution stations throughout the building and to individual uses from the stations.

Warm seal water is also supplied and distributed by two pumps, one normally operating. The pumps draw suction from the primary suction header and supply several distribution stations. When the primary coolant system is shutdown, the warm seal pumps are shutdown and primary seal water is valved to supply the warm seal system.

Primary system pH is controlled by injection of nitric acid and/or by varying flow through the bypass demineralizer. Two positive displacement pumps, one normally operating, draw from an acid supply and discharge into the reactor return line. A pH recorder-controller automatically adjusts the pump speed as required. Varying the portions of cation and anion flow also influences pH and reduces the amount of acid required.

b. Controls and Instruments

Primary system flow, pressure, and tank water level measurements are achieved by using standard pneumatic Δ P cell, transmitters, and receivers. Except for main flow control, the process control valves are remote pneumatically operated, either automatically from a controller or from a manual control station. The valves may be either air-to-close or air-to-open, the selection based on fail-safe operation.

Radioactivity within the coolant loop is monitored by a fission break monitor. A sample of the bypass cation effluent is routed through a small anion column to a drain. The I-135 collected on the columns is monitored by a scintillation detector.

A supply of demineralized water from the primary gland seal water pumps is monitored by ten N-16 monitors and then discharged into the warm waste system. The monitors are inserted through the vessel bottom closure, eight in the beryllium surrounding the core and two into the center flux trap baffle. The outlet from each tube is monitored to indicate the relative flux or power level throughout the reactor.

c. Operation

During reactor shutdown, the vessel top closure is opened and the primary system placed in shutdown conditions. These conditions are : (1) pressure reduced to atmosphere, (2) flow provided by one emergency pump, and (3) the reactor vessel upper drain valve opened. Flux runs are conducted with the system in normal shutdown conditions with the exception that flow is provided by the operation of both emergency pumps. At the completion of the shutdown and flux run, if scheduled, the vessel is closed, filled, and vented, and the primary system returned to operating conditions. Normal operating conditions are:

(1) System pressure 355 psig at the reactor inlet.

(2) Reactor pressure drop 100 psig giving a total flow of approximately 48,000 gpm.

(3) Pressurizing flow 200 gpm.

(4) Degassing flow approximately 270 gpm.

(5) Gland seal input approximately 70 gpm.

(6) Bypass demineralizer flow 200 gpm.

(7) pH 5-6.

(8) One emergency pump operating with 250 gpm recirculation flow.

(9) Reactor inlet temperature 125°F.

(10) Reactor outlet temperature 167°F.

2. Secondary Coolant System (SCS)

a. Description

Four secondary coolant pumps circulate secondary cooling water through the shell side of the primary heat exchangers to remove the reactor heat from the primary coolant system. The heated secondary cooling water then flows over the cooling tower where the heat is dissipated to the atmosphere. The water then flows from the cooling tower basin to the coldwell and the secondary pump suction to complete the secondary coolant loop.

The cooling tower is equipped with six fans that can be operated at two speeds forward and one reverse. The heat removed from the secondary cooling water is controlled by adjusting the fan speeds to maintain the desired secondary coolant water temperature. The fans are periodically operated in reverse during cold weather to remove any ice accumulation from the cooling tower.

Secondary water losses due to evaporation and blowdown are compensated by makeup water pumped from the TRA raw water storage tanks. This makeup water and the circulating secondary cooling water are treated with sulfuric acid, Dianodic (Betz E-194), and chlorine to minimize piping corrosion, biological fouling of the cooling water, and chemical attack on the cooling tower wooden structure. Solids are concentrated by evaporation of secondary cooling water in the cooling tower. A portion of the circulating secondary coolant is "blown down" to the waste to control the solids concentration.

Interconnection of the secondary and UCW systems is provided in two places. The systems are interconnected in the cooling tower pumphouse to provide secondary cooling water flow to the UCW system in case of mechanical or electrical failure of both UCW pumps. In the reactor building first basement, the two systems are interconnected through a line containing a flow control valve. This valve serves a dual purpose: (1) it opens to a preset stop during a commercial power failure to provide emergency flow of UCW to the secondary coolant system for removal of reactor decay heat, and (2) the valve is positioned with a manual loader during low power reactor operation and flux mappings to provide the necessary controlled low flow rates of cooling water to the primary heat exchangers.

Radiation monitors are installed in the secondary coolant outlet line of each primary heat exchanger to detect leakage of radioactive primary coolant into the secondary coolant system.

b. Operation

(1) Flow

Secondary cooling water is circulated through the secondary system by four, vertical turbine-type pumps rated at 8600 gpm and driven by 350 hp motors. The flow of secondary water through the shell side of the heat exchangers is varied to regulate the amount of heat removed from the primary system, therefore maintaining a constant primary coolant reactor inlet temperature.

(2) Temperature

The temperature of the secondary water is controlled by regulating the air flow through the cooling tower. The operator adjusts fan speeds to maintain the desired secondary coolant temperature. The fans are controlled from push-button stations on the tower or in the process control room.

(3) Emergency Flow

The secondary system acts as an emergency flow source for the UCW system. The connecting line between the two systems in the cooling tower pumphouse contains a check valve that is normally held closed by the higher pressure of the UCW system (75 versus 63 psig). When the UCW system is shutdown or the pumps stop operating due to diesel electrical power failure, the secondary system pressure will open the check valve and approximately 2000 gpm of secondary cooling water will then flow through the UCW system.

All four secondary coolant pumps stop if there is a commercial power failure. To provide for removal of reactor decay heat, the secondary and UCW systems are interconnected in the reactor first basement. When commercial power fails, a control valve in this connecting line opens to a preset stop to allow 1500 gpm of utility cooling water flow to the shell side of the primary heat exchangers. This valve must be reset upon restoration of commercial power. This control valve can be positioned manually to provide controlled flow rates up to 2000 gpm of utility cooling water to the secondary coolant system. This flow path is utilized for removal of primary coolant heat during lower power runs and flux mapping.

(4) Cooling Tower Blowdown and Makeup

The evaporation of the secondary water in the cooling tower results in an increasing concentration of solid materials in the secondary water. An equilibrium concentration of total solids at four times the solids concentration in the makeup water is accomplished by purging some of the high solid concentration water from the secondary system and replacing it and the evaporation losses with low solid concentration makeup water from the TRA raw water storage. Makeup water is pumped to the coldwell by one of two cooling tower makeup pumps located in the MTR raw water pumphouse. One pump will provide 2500 gpm, and this added to the 600 gpm discharged from the experimental cubicle air chillers provides sufficient makeup to overcome total evaporation and blowdown losses of approximately 2700 gpm when the reactor is operating at 250 MW. The makeup water flow from the cooling tower makeup pumps is regulated to maintain a constant coldwell water level.

It would be inefficient and expensive to purge any more chemicals to the drain system than is necessary; yet chemical and hardness ion concentrations can get too high due to evaporation. Optimum operating conditions for the secondary system occur when the hardness ions are about four times more concentrated in the secondary water than in the raw makeup water. An operator determines the total hardness concentration every four hours and adjusts the blowdown rate to maintain total hardness at four cycles or 600 to 840 ppm.

(5) Water Treatment

The pH level and Dianodic concentration must be accurately maintained between set control limits to minimize piping corrosion and chemical attack on the cooling tower structure. Sulfuric acid is added by vertical positive displacement pumps with a capacity of 0 to 25 gph. The speed of the acid pump motor is automatically regulated by a recorder-controller to maintain secondary coolant pH between 6.0 and 6.3. Dianodic injection into the secondary cooling water is accomplished with two 0 to 26 gph positive displacement pumps to maintain Dianodic concentration at 11 to 14 ppm.

Concentrated chlorine solution is added three times a week to the secondary coolant system to minimize biological fouling of the cooling water. The chlorine concentration in the circulating coolant is increased to and maintained at 1 ppm for four hours to ensure that all types of biological material are eliminated.

3. Supplementary Water Systems

a. Utility Cooling Water Systems (UCW)

(1) Description

The UCW system supplies treated water for cooling the HDW system, the diesel generators, and in some cases the primary system. The system uses the cooling tower basin as its source of water and the cooling tower to expel the absorbed heat. The system is designed to continuously supply 3050 gpm at 75 psig.

The UCW pumps take suction from the deep well portion of the cooling tower coldwell and supply 2050 gpm to the HDW heat exchangers and 500 gpm to each diesel generator system. Each line to the diesel generator system carries UCW in parallel through the tube side of the lube oil heat exchanger and the shell side of the combustion air cooler. The two lines join and UCW flows through the tube side of the jacket water heat exchanger and into the system return header.

The supply line to the HDW heat exchangers carries UCW in series through the shell side of the HDW heat exchangers. The heated UCW is then returned to the secondary coolant system return header and then to the cooling tower.

A line connecting the secondary pump discharge header to the UCW pump discharge header provides a backup for a loss of the UCW pumps. The check valve in this line is normally held shut by the higher discharge pressure of the UCW pumps.

The UCW and SCS are also connected in the reactor building by a line containing a flow control valve. This valve is used to control flow from the UCW to SCS during a commercial power outage or during reactor flux mapping.

The fire-water system provides backup for the UCW supply to the diesel engines. A flow control valve in the fire-water line is normally closed. This valve automatically opens on low supply pressure to the diesels.

The UCW pumps are installed in the deepest section of the cooling tower coldwell. This location allows the use of these pumps for draining or pumping out the coldwell.

(2) Operation

Under normal operation, one UCW pump will supply 3050 gpm to the UCW system. In the event of a running pump failure, the standby pump will automatically start..

On loss of diesel power and subsequent loss of the UCW pumps, the check valve between the secondary pumps discharge header and the UCW pumps discharge header will open. This will allow approximately 2000 gpm of secondary coolant water to serve the UCW system.

On loss of commercial power and subsequent loss of the secondary pumps, a control valve opens automatically to a preset position to pass 1000 gpm of UCW to the primary heat exchangers for reactor decay heat removal. This control valve is also used during reactor flux mapping operations to remove reactor heat via the primary heat exchangers. A manual loader permits increasing or decreasing the flow quantity to the SCS during lower power reactor operations. The flow of UCW to the HDW heat exchanger is 2050 gpm during normal operations. On loss of commercial power, this flow is automatically reduced to 1050 gpm by another control valve.

On complete loss of commercial and diesel power with loss of both secondary cooling and utility cooling water pumps and subsequent loss of UCW pressure, a control valve opens to pass approximately 500 gpm fire-water for emergency operation of one diesel engine.

In the event of an instrument air outage, one control valve will open to supply 1000 gpm to the secondary heat exchangers and another will close reducing the UCW flow to the HDW heat exchangers to 1050 gpm.

b. High Pressure Demineralized Water System (HDW)

(1) Description

The HDW system is a pressurized demineralized water loop used for removing heat from the in-pile experiments and experiment auxiliary equipment. It is designed to supply a total flow of 1635 gpm at 200 psig. Since the loop is constructed of carbon steel (except for arsenical copper heat exchanger tubes), a sodium chromate corrosion inhibitor is injected into the system to minimize carbon steel corrosion.

Of the 1635 gpm discharged by the HDW circulation pumps, 575 gpm passes through the tube side of one heat exchanger to be cooled from 130° to 100°F by 85°F UCW on the shell side. This 100°F HDW supply is used to remove heat from the experimental loop canned rotor pumps and purification coolers. The remaining 1060 gpm of 130°F water is used to remove heat from the experimental loop heat exchangers. The HDW is discharged from the experimental heat exchangers at 196°F, and when mixed with the 120°F HDW from the experimental loop equipment, the temperature of the combined flow is 170°F. The 170°F HDW is cooled to 130°F on the tube side of a second heat exchanger, by 85°F UCW on the shell side. The HDW then flows to the suction of the circulation pumps to complete the circuit.

A 100 gallon carbon steel expansion tank is connected to the system at the pump suction and is used to accommodate system volume changes, dampen pressure surges, and maintain a constant 140 psig suction pressure to the circulation pumps.

The level in the expansion tank is automatically maintained by either adding 245 psi gland seal water through one valve or draining water through another.

The HDW supply pressure is held constant by a pressure control valve which controls bypass flow between the pump discharge and suction.

(2) Operation

Under normal operation, one pump will be running on diesel power and the standby pump will be selected for commercial power. In the event of a diesel power failure or a running pump failure, the standby pump will automatically start on commercial power and continue to supply water to the HDW loop.

The chromate concentration in the loop is held between 700 and 800 ppm by periodically pumping concentrated sodium chromate solution into the system with a chemical feed pump.

In the event of an instrument air outage, all system components fail to the safe position and the system continues to supply water for cooling.

c. Low Pressure Demineralized Water System (LDW)

(1) Description

Demineralized water for the Test Reactor Area is produced and distributed from the Demineralizer Building, MTR-608. The demineralized water system is comprised of three demineralizer trains with a combined capacity of 600 to 650 gpm, two 100,000 gallon water storage tanks, two 500 gpm water transfer pumps, and two 1000 gpm reactor flush pumps. Operation of this system is under the direction of the MTR Operations Branch.

Demineralized water received at the ATR is distributed throughout the plant as a supply of high purity water. The normal uses of LDW are: primary system flushing, primary system makeup, experimental system makeup, experimental system cooling, canal system filling and purging, underwater saw operation, reactor transfer tube operation, and as a source of purified water for the several process and sample laboratories.

(2) Operation

During normal operation LDW to the ATR flows through a four-inch bypass line. This line will adequately supply an LDW flow of 300 gpm at 80 psig. When flow through the bypass exceeds 300 gpm, the building pressure will start to decrease. This in turn lowers the gland seal pump suction and discharge pressure and may effect the N-16 monitor and gland seal flows. Thus, for operation where the LDW flow to the building will exceed 300 gpm, a valve is opened.

At the MTR Demineralizer Building, one 500 gpm demineralized water transfer pump will normally be running to supply LDW to MTR-ETR and ATR. On a low pressure signal, the second 500 gpm pump will start automatically. Thus, both pumps have a capacity of about 1000 gpm for all three plants. To exceed this 1000 gpm flow, a 1000 gpm flush pump must be manually started.

d. Raw, Fire, and Domestic Water Systems

(1) Description

The Test Reactor Area raw water and fire-water systems supply a continuous flow of raw water to the various facilities for cooling tower makeup water, demineralizer plant raw water, miscellaneous cooling services, fire protection, and potable and domestic water services.

Raw water is drawn from three deep-wells, located along the north perimeter of the TRA area, by three vertical turbine pumps which discharge into three 500,000 gallon ground level storage tanks. Water from the three 500,000 gallon tanks feeds six MTR-ETR feed water pumps, two fire pumps, and the two ATR cooling tower makeup pumps.

The MTR-ETR feed water pumps supply raw water to the 150,000 gallon raw water overhead reservoir, plant demineralizer, normal fire-water loop, and raw water distribution system. The ATR raw water supply taps the existing TRA raw water lines near the TRA Demineralizer Building.

The fire-water system, normally floating on the raw water overhead reservoir, is supplemented by the two fire pumps, one electric and one gasoline. One pump will automatically start in the event of a pressure drop in the fire-water loop piping. The ATR fire-water loop taps the existing TRA fire loop east of the ATR reactor building.

Domestic or blended water is supplied from the TRA Demineralizer Building where raw water has been softened, stored in a 10,000 gallon storage tank, and pumped to the various distribution points by one of two blended water pumps.

(2) Operation

(a) Raw Water System

The following services are provided by the raw water system in the ATR area: bearing and stuffing box coolant for the primary coolant pumps and the primary pressurizing pumps; cooling water to various air conditioning units, air washers, and air handling units throughout the building; cooling water for the condensate heat exchanger; cooling water for the experimental loop surge tank level transmitter impulse lines; and a water supply for the rod access room sump eductor. Cooling tower makeup and the cooling tower chlorinator are also supplied by raw water.

(b) Fire-Water System

ATR outside fire protection is afforded through a system of nine fire hydrants and five hose houses located strategically around the area in such a manner that each building is serviced by at least two hydrants.

Building protection is accomplished in three ways: fire-hose racks, six sprinkler systems servicing 16 areas of the building, and many portable extinguishers.

The ATR cooling tower is protected by a dry pipe, pressure actuated, deluge system and two fire-hose stations located on the top of the cooling tower.

Additional fire-water is provided for utility cooling water emergency makeup and emergency fire-water supply to the reactor vessel.

The reactor spray system, for washing the air and walls of the reactor room, is also supplied from the ATR fire loop. The spray system is provided to wash the area of fission product contamination, especially iodine, which might result from a reactor accident.

(c) Domestic Water System

Domestic water (potable, blended, or cold soft water) is supplied from common TRA facilities. Uses in the ATR building include laboratories, drinking fountains, toilets, showers, emergency showers, and diesel-generator jacket water makeup.

D. Waste Disposal

1. Uncontaminated Waste

Two classifications of uncontaminated liquid waste from the ATR are made. Water from the cooling tower blowdown and basin drain, heating and ventilating equipment, and transmitter impulse line cooling coils is designated as cold waste. This water flows by gravity to manhole 22C and then to the TRA disposal well.

Uncontaminated waste from the ATR sanitary facilities is designated as sanitary waste and flows by gravity to the TRA sewage treatment plant.

2. Warm Waste System

a. Description

The flow diagram for the warm waste system is shown in Figure 41. Low-activity waste from the rod access area sump, canal cleaning system, canal drains, bypass demineralizer drains, building drains, reactor top-head drain, degassing tank overflow drain, fission break monitor sample drain, and N-16 monitoring drains flow by gravity through an internal tank strainer into the 5000-gallon warm waste tank. The tank is located in a shielded vault below the second basement floor.

b. Operation

The warm waste tank is drained by two 200-gpm, vertical, tank-mounted pumps, one of which is a spare. A level switch automatically starts and stops both pumps. The pumps can also be started manually from the process control room where a high tank level is annunciated. The pump motors are accessible at all times and are located on the motor floor which is above and shielded from the warm waste tank. One pump is supplied from the commercial power system and the other from the diesel power system.

In an extreme case it is possible to exceed the removal capacity of both warm waste pumps, causing the tank to overflow. Contaminated water could back up into the vent line, flow into the heating and ventilating ductwork and back fill the hot waste tank cubicle sump, causing a considerable spread of contamination. For this reason, when draining a large amount of water into the warm waste system, close surveillance of the tank level is mandatory and the draining rate kept within the limits of the pumps.

The warm waste tank pumps are equipped with a recirculation line which is used to mix the tank contents in order to assure representative samples for activity level determinations. MTR operators will administratively control discharge of ATR warm waste to limit activity in the leaching pond.

The warm waste is pumped to the 30-inch line from the MTR Process Water Building to the retention basin. The liquid is ultimately discharged to the leaching pond.

The warm waste tank strainer can be removed for cleaning or for pumping out the warm waste tank by the use of a portable pump.

The warm waste tank pump discharge line can be drained back into the warm waste tank to clear the discharge line if the warm waste sump tank pumps are to be removed for maintenance. The warm experimental waste tank area has a floor sump, with a level float switch which annunciates an alarm on high water level.

In general, all drains to the warm waste system not equipped with covers are trapped, preventing the escape of air activity. These drains with covers are kept closed when not in use, except for a select few which are left open to allow a passage of air down through the system and out the cubicle exhaust plenum. These specific drains are marked as to their function.

In addition to warm waste collections made in the warm waste tank, a sump pump in the heat exchanger vault sump discharges liquid

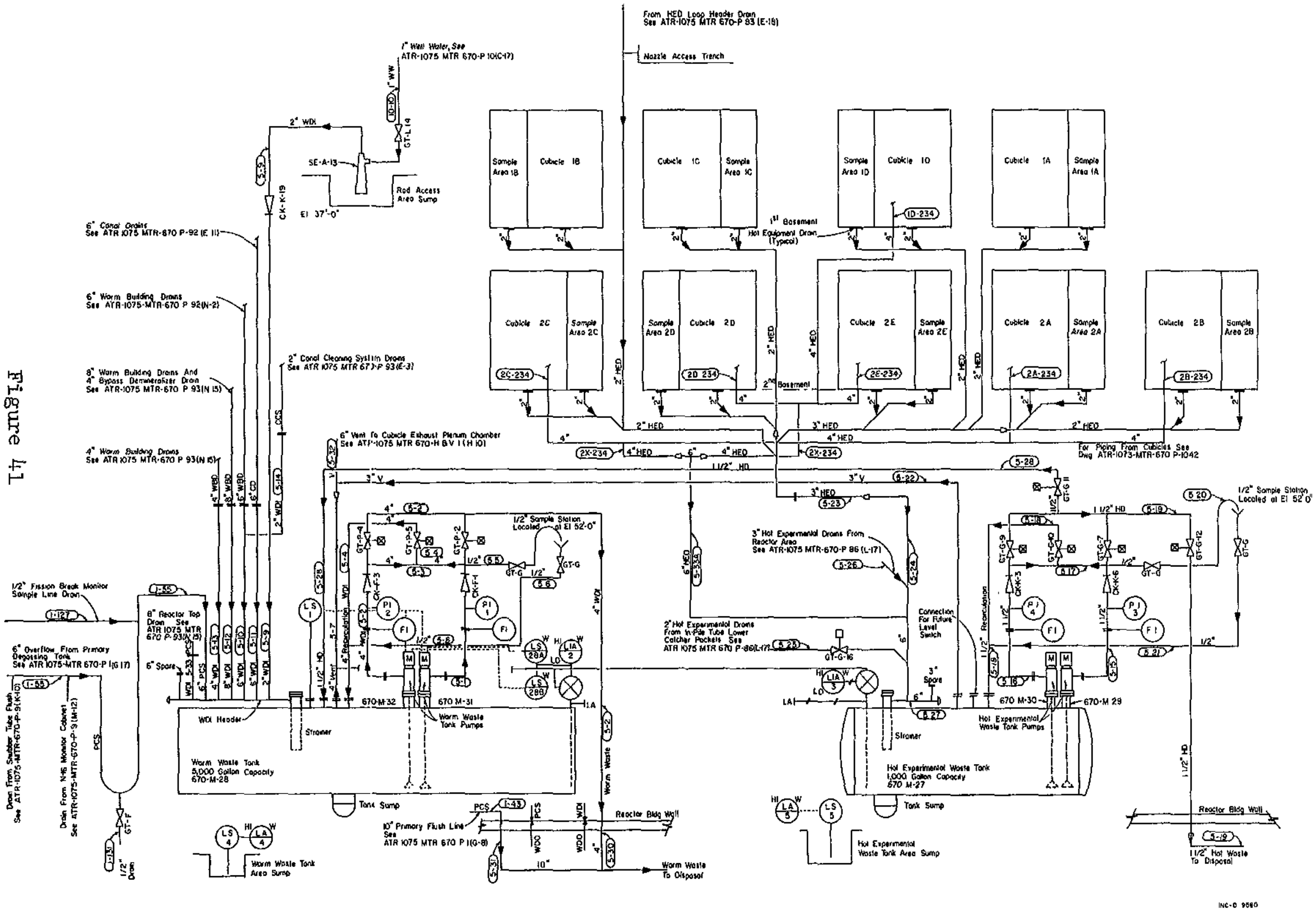


Figure 41

ATR Waste Handling and Disposal System

waste into the 10-inch reactor flush line. The sump pump operates automatically to keep the heat exchanger vault pit empty of water due to leakage on either the primary or secondary side of the heat exchangers. The sump pump is also used when draining the primary or secondary side of the heat exchangers.

The tank pumps are cast iron construction with steel column pipe. The piping and valves in the reactor building are stainless steel. Inside and outside buried lines which lead to the MTR-ETR area are ductile cast iron.

The primary coolant system flush water drain joins the warm waste sump tank drain for disposal to the MTR facilities. The primary coolant flush drain piping is austenitic stainless steel inside the reactor building and is ductile cast iron outside the building.

3. Hot Experimental Waste System

a. Description

The hot experimental waste system provides drainage for high activity radioactive waste from experimental sources. These sources include loop cubicle and sample area drains, loop header drains around the reactor vessel on the main floor, nozzle trench drain, and in-pile tube lower catcher pocket drains. Block valves admitting water to the system are closed except at the time of draining. The in-pile tube lower catcher pocket drains are provided with a common block valve between the drain and the hot waste tank which is also normally closed.

Lateral and riser piping carry the waste water to the 1000 gallon hot experimental waste tank. As the water enters the tank it passes through a removable strainer and is then stored. The tank, located in the north cubicle under the motor floor area, is also vented to the cubicle exhaust plenum providing a slight vacuum on this system.

The hot experimental waste tank is drained by two vertical, tank-mounted, 25 gpm pumps, one of which is a spare. One pump is supplied from commercial power and the other from diesel power. The pump motors are accessible at all times for maintenance and are located on the motor floor which is above and shielded from the hot waste tank vault.

All drains to this system are covered when not in use with the exception of those drains designated to remain open to provide a passage of air down through the system and out the cubicle exhaust plenum.

b. Operations

The tank level is indicated and a high level actuates an alarm on the process control panel. The pumps are started and stopped by manual control from the process control panel.

The hot experimental waste pumps are equipped with a recirculation line which mixes the tank contents so that representative samples can be taken to determine the activity. The hot experimental waste is normally pumped to the existing underground MTR hot waste storage tanks. If the fluid has an activity level below that permitted in the warm waste system, the hot experimental waste can be pumped to the larger warm waste tank. This prevents overloading the hot waste disposal system with low-level wastes.

For pumping out the hot experimental waste tank residue, a portable pump is inserted through the connection normally occupied by the strainer. The pump discharge line can be drained back into the hot experimental waste tank to clear the discharge lines prior to removing the hot experimental waste tank pumps for maintenance.

The hot experimental waste tank vault has a floor sump with a level float switch which enunciates an alarm on high-water level.

The tank, pumps, piping, valves, and fittings in this system are austenitic stainless steel.

4. Solid Waste

Solid radioactive wastes are disposed of in the existing NRTS burial grounds using the same type of facility hauling and burial equipment as used for the MTR-ETR.

5. Gaseous Waste

The hot experimental waste tank, the warm waste tank, all drain lines emptying into these tanks, and the two waste tank vaults are maintained under a negative pressure by means of a supplementary exhaust fan which discharges to the main exhaust system. All drain lines are orificed to assure a negative pressure in the waste drain systems. This provides positive removal of radioactive gases present in the liquid wastes. These drain and vent lines have no water seals or other restrictions which could act as a collection point for radioactive crud.

E. Heating and Ventilating System

1. Description

The ATR building ventilation system is sectionalized; and the individual systems are independent of each other, with certain specific areas being secured by the radiation monitoring system. For all practical purposes, the flow of air is from a clean to a potential contaminated area to exhaust.

Instruments are located throughout the building and throughout the exhaust system to sense radioactivity. This system is known as the "radiation monitoring system" (RMS). The RMS is interlocked with the heating and ventilating system and, depending on air activity or radiation, isolates the various systems or the entire system.

The main reactor floor and the first and second basements are considered gastight areas and are serviced by three supply units, a main exhaust system, and roof ventilators. The supply systems close automatically on a high radioactive signal; the exhaust system and roof ventilators are also interlocked with the RMS to prevent discharge of high activity to atmosphere. All duct work which passes through fire walls or through floors incorporates dampers at the point of penetration to ensure closure and prevent carry-over of contaminated air or smoke in case of fire.

The various areas are provided with auxiliary exhaust systems which are utilized in the summer to relieve the 100 percent outside air supply. Some of the systems are utilized the entire year when servicing rest rooms, locker rooms, and hooded connections. These systems use roof ventilators or blowers for exhausting to the atmosphere.

The heating system design is based on a winter ambient temperature of minus 20°F. Steam is supplied from the MTR steam plant at 125 psig. All steam condensate from the heating systems is collected and returned to the steam plant. In the winter, 20 to 80 percent of the air is recirculated to conserve heat; in the summer, when the outside temperature is 60°F or above, recirculated air is reduced to approximately zero.

The counting room, reactor control room, and the process control room each have a self-contained, air-treatment unit that regulates the temperature at 72°F winter and summer. The cubicles, sub-pile room, and the rod access room each have coolers with circulating fans to maintain a space temperature of approximately 74°F. Well water is used as a coolant, and the units operate winter and summer. These systems recirculate the air within the cubicle or room and are independent of the heating and ventilating systems.

A graphic representation of each piece of equipment and system is provided on the control panels located at three different areas.

2. Systems

a. System Number 1

System number 1, commonly called the gastight area, consists of the main reactor floor, the outer shim rod drive service area, safety rod drive service area, piping corridor, and the main building first and second basement area. Normal air flow through this system is 64,800 cfm which is approximately six changes of air per hour for the main floor and four changes of air per hour for the first and second basements.

This area may be partly isolated or the entire area sealed off due to high radiation and/or air activity depending on the severity as controlled by the RMS relays Nos. 1 and 2.

During summer operations, the air supply is drawn in from outside through filters, an air washer, and regulating dampers. During the winter, approximately 80 percent of the supply is outside air and 20 percent is recirculated. The air passes through filters, regulating dampers, and a double bank of steam heating coils designed to maintain a space temperature of 72°F.

b. System Number 2

System number 2 (HVS-2) services the critical facility area which includes the critical facility reactor floor, office area, rest rooms, hallways, storage room, and sample preparation laboratory. Normal air flow through this system is 12,500 cfm which is approximately four changes of air per hour.

This system does not tie-in with the gastight area. However, it is adjacent to the supply fan which is shut down on the RMS signal.

During summer operation, the air supply is drawn in from the outside through filters and regulating dampers. During the winter, approximately 14 percent of the supply is outside air and 86 percent recirculated. The air passes through filters, dampers, and a single bank of steam heating coils designed to maintain a space temperature of 72°F.

c. System Number 3

System number 3 (HVS-3) services the storage canal area, the general storage and lay-down area, and the hood over the primary acid addition system. Normal air flow through the system is 23,500 cfm which is approximately four changes of air per hour.

This system does not tie into the gastight area. However, it is adjacent to the supply fan which is shut down on the RMS signal.

During summer operations, the air supply is drawn in from the outside through filters and regulating dampers. During the winter, approximately 32 percent of the supply is outside air and 68 percent is recirculated. The air passes through filters, dampers, and a single bank of steam heating coils designed to maintain a space temperature of 92°F.

d. System Number 4

System number 4 (HVS-4) services the second floor offices, the rest rooms, and the utility spaces on the first floor. Normal air flow through this system is 13,500 cfm which is approximately ten changes per hour for the offices, fifteen changes in the rest rooms, and four changes per hour in the utility areas.

The reactor shift supervisor's office, corridor, and office 110 are supplied with air from system 4; the reactor control room is supplied by air conditioning system 2. Office 110 is part of the gastight area and is equipped with dampers to separate the two systems in case of RMS signal.

During summer operation the air supply is drawn in from the outside through filters and regulating dampers. During the winter, approximately 25 percent of the supply is outside air and 75 percent is recirculated. The air passes through filters, dampers, and a single bank of steam heating coils designed to maintain a space temperature of 72°F.

e. System Number 5

System number 5 (HVS-5) services the first and second basement (north side), the battery room, primary pump motor area, and the diesel generator room and adjacent utility space. Normal air flow through this system is 79,250 cfm which is approximately four changes of air per hour.

The first and second basements are interconnected with the gastight area, and include a butterfly damper to separate the two areas. The damper is controlled by the RMS, which closes the damper on a high radiation signal, stops the supply fan, and seals the basements.

During summer operations, the air supply is drawn in from the outside through filters, an air washer, and regulating dampers. During the winter, approximately 22 percent of the air supply is outside air and 78 percent is recirculated. The air passes through filters, dampers, and a single bank of steam heating coils designed to maintain a space temperature of 60°F. In addition, a 5 kW electrical reheat coil is located in the branch duct to the utility area and is designed to maintain a space temperature of 70°F.

f. Auxiliary Systems

(1) Critical Facility Counting Room Air Treatment System

Air Treatment System (HVA-1) supplies 5050 cfm of treated air to the critical facility counting room, winter and summer. The unit recirculates 80 percent of the air and uses 20 percent outside air. Seven hundred and fifty cfm of air from the counting room is discharged into the sample preparation laboratory.

The unit is a self-contained, 10-ton unit with a supply fan, damper, air filter, steam coil, cooling coil, and two Freon compressors designed to maintain a space temperature of 72°F.

(2) Reactor Control Room Air Treatment System

Air Treatment System (HVA-2) supplies 7000 cfm of treated air to the readout, instrument repair, reactor control, and instrument room, winter and summer. The unit recirculates 80 percent of the air and uses 20 percent outside air. The control and instrument room is provided with a relief duct and RMS-operated butterfly damper.

The unit is a self-contained, 20-ton unit with additional electrical reheat coils in the branch ducts to the readout room, reactor control, and instrument room. The unit is equipped with a supply fan, damper, air filter, steam coil, cooling coil, and two Freon compressors to maintain a space temperature of 72°F.

(3) Process Utility Control Room Air Treatment System

Air Treatment System (HVA-3) supplies 2800 cfm of treated air to the process utility control room, winter and summer. The unit recirculates 80 percent of the air and uses 20 percent outside air. Discharge of air from this system is over the stairway west of the control room.

The unit is a self-contained 7 1/2-ton unit with a supply fan, damper, air filter, steam coil, cooling coil, and one Freon compressor designed to maintain a space temperature of 72°F.

(4) Heating and Ventilation System for the Cooling Tower Pump House

Ventilation of the cooling tower pump house is by two roof exhaust fans rated at 25,500 cfm. When the fans are manually started, two motor-operated dampers open to allow outside air to enter the building. Heat is furnished by three steam-operated space heaters rated at 221,000 Btu/hr and are thermostat controlled. The chlorine room which is sealed off from the main pump house is ventilated by a roof exhaust fan rated at 450 cfm.

(5) Steam Condensate System

System HVP-1 collects steam condensate from the reactor building and the cooling tower pump house, and returns the condensate to MTR 609 for reuse.

3. Operations

a. Normal Operations

Each system can be operated manually or automatically from its individual graphic panel. Part of the units should be operated in the automatic position, winter and summer; those units with water washers should be operated in either the winter or summer position.

Steam coils are used for heating the air just after the air enters the building plenum. The air temperature is controlled by thermostats which are located in the individual areas. The steam coils are protected against freeze-up by a thermostat locally mounted which overrides the room thermostat.

The dampers are all operated by spring return air cylinders except the main exhaust damper near the stack which has a double-acting air cylinder. All dampers close when the air pressure drops to 100 psig; normal air pressure is 125 psig. When an RMS actuates, a three-way solenoid valve is de-energized venting the cylinder air pressure, and the return spring closes the damper. Upon resetting the RMS, the solenoid valve is energized and the damper opens. In addition to automatic operation, the dampers may be controlled manually. A small air tank is pressurized by plant air and connected to the air cylinder through a manual three-way valve. The damper may be positioned manually by this valve at any time.

Flow of air through the H and V system has been balanced; to maintain this balance, all doors leading from one system to another must be closed. Unless unforeseen changes are made to the systems, the louver and damper setting should not be changed from their present setting. Balancing the system requires many man-hours of work.

After loss of power or following an RMS shutdown, the H and V system must be restarted manually from their respective panels. The RMS sends out signals every six seconds, so it is possible to have an RMS shutdown and six seconds later restart the system.

b. Abnormal Operations

The radiation monitoring system (RMS) has the function of isolating the various gastight areas and adjacent areas in case of high radiation level and/or air activity.

An RMS No. 1 shutdown stops all supply fans and exhaust blowers and closes all dampers in the air ducts to completely seal off the entire gastight area from the adjacent areas. An RMS No. 1 shutdown is actuated by a signal from either the stack breech monitor or the main exhaust plenum monitor.

An RMS No. 2 shutdown stops the gastight area supply fans and the exhaust fans servicing the gastight area except the main building exhaust fans and closes dampers to isolate the first and second basements and adjacent area. An RMS No. 2 shutdown allows the reactor main floor to be vented to the stack. Since the main reactor floor will be under a slight vacuum and the adjacent area under a slight pressure, leakage between areas will be inward. An RMS No. 2 shutdown is actuated by a coincidence of several monitors located on the main reactor floor and second basement.

An RMS No. 3 shutdown stops all supply fans and exhaust fans, and closes all dampers to isolate the critical facility area. No other areas are affected by this shutdown. An RMS No. 3 shutdown is actuated from either of two monitors located in the critical facility area.

An RMS No. 4 shutdown stops all supply fans and exhaust fans and closes all dampers to isolate the canal and laydown area. No other areas are affected by this shutdown. An RMS No. 4 shutdown is actuated from either of two constant air monitors located in the canal and laydown areas.

c. Emergency Operations

Forced evacuation of the building may be accompanied by a loss of commercial power or diesel power or both. The "emergency electrical diesel generator start-up panel" (ESP) provides a remote means for reactivating a diesel generator and connecting it to the diesel bus for restoration of essential services.

F. Electrical Systems

1. General Description

Electrical power for the National Reactor Testing Station is supplied from the Northwest Power Pool and is transmitted via the Goshen substation to the Scoville substation. From the Scoville substation a 132 kV loop is used to furnish power to the site substations. From Scoville the 132 kV loop extends to ICPP, TRA, NRF, TAN, EBR-II, and Spert substations and then returns to Scoville.

At the TRA substation, the 132 kV is reduced to 13,800 volts for distribution to MTR, ETR, and ATR. The 13,800 volt commercial power is supplied to ATR and ETR by two 20,000 kVA 132/13.8 kV transformers. The ETR and the ATR share common terminals at each transformer; however, there are individual feeders to each plant.

The ATR electrical distribution facilities consist of five separate systems as follows: (1) commercial power, (2) diesel power, (3) diesel-commercial power, (4) instrumentation ac battery-backed power, and (5) utility dc power.

2. System Description

a. Commercial Power System

This consists of a 13,800 volt system, a 4,160 volt system, a 480 volt system, and a 120/208 volt lighting distribution system.

b. Diesel Power System

To supply a source of power which is independent of commercial power, two diesel driven generators have been installed. The loads from the diesel bus have been selected so that important plant loads will be operated from or will be automatically transferred to the diesel power system in the event of a commercial power outage. One diesel generator will run continuously while the other unit will be on standby. All ATR and experiment pumps, heaters, and ventilation equipment necessary for safe reactor shutdown on loss of commercial power are operated from or will be transferred to the diesel bus.

The diesel generators have a capacity of 1875 kVA at 0.8 power factor (1500 kW), 4160 volts, 60 cycle, 3 phase. Four hundred and eighty volt power is also available for this system.

The diesel engines are started by injecting high pressure air into the cylinders. This high pressure air is supplied by two air compressors which are located in the auxiliary equipment room of the second basement. The diesel fuel for the units is supplied from the TRA diesel fuel storage tanks which are located at the site tank farm northeast of the ATR.

c. Diesel-Commercial System

(1) 480 Volt Diesel-Commercial Motor Control Center (670-E-15)

The diesel-commercial motor control center may be energized from either the 480 volt diesel bus or the 480 volt commercial bus B. The normal source of power, however, is the 480 volt diesel bus. If a diesel power outage should occur, the source of power will automatically be transferred to the commercial bus. When diesel power has been restored, the motor control center will automatically be transferred back to the diesel bus. The 480 volt diesel and commercial feeder breakers are electrically interlocked so that it is impossible to have both breakers closed at the same time.

The purpose of the diesel-commercial system is to have a very reliable source of power available for certain important plant loads. The following are energized from the 480 volt diesel-commercial motor control center: (a) regulating rod amplidyne motor generators, (b) transformer for reactor control rod drives, (c) transformers for lighting distribution panels (power to all HP instruments), (d) 480 volt experimenters power panels, (e) primary emergency coolant pump and warm seal water booster pumps, and (f) diesel engine auxiliary equipment.

(2) 120/208 Volt Distribution

Power at 120/208 volts is distributed from four panels designated as 120/208 volt diesel-commercial distribution panels.

Each panel includes manually operated air circuit breakers for control of feeders to lighting panels, reactor and process control panels, data processing system, and communication and alarm panels.

d. Instrumentation AC Battery-Backed Power System

In the operation of a nuclear reactor, it is mandatory that power be available for reactor instrumentation and control. The instrumentation ac battery-backed power supply will supply power for nuclear instrumentation and emergency shim drive insertion. The emergency shim insert bus is actuated upon loss of the normal power source, i.e., the diesel-commercial power. The instrumentation ac battery-backed power system can supply power for approximately 50 minutes after all other power sources are lost. This ensures safe reactor shutdown in the event of unforeseen power outages.

The instrumentation ac battery-backed power system consists of two motor generators; a 120-cell, 250-volt battery bank; a standby transformer; and the necessary control panels.

The instrumentation ac power motor generator (hereafter referred to as dc-ac MG set) is a dc motor driving an ac generator. The instrumentation dc power motor generator (hereafter referred to as ac-dc MG set) is an ac motor driving a dc generator.

The dc-ac MG set will normally supply power at 120/208 volts, 60 cps, 3 phase to the following: (1) reactor control instrumentation and protection, (2) data system electronics, and (3) shim motor drive emergency insert bus.

The ac generator 120/280 voltage and frequency output is closely regulated as it is required for instrumentation power. The dc motor of the dc-ac MG set is energized from the dc generator of the ac-dc set and battery bank 670-E-59. The ac motor of the ac-dc MG set is energized from the 480 volt diesel bus.

During normal operation, the ac-dc MG set will be supplying power to the dc-ac MG set and simultaneously float charging the 250 volt battery bank. In the event of a diesel power outage, the ac-dc MG set will stop. The dc-ac MG set will continue to run, being supplied power from the battery bank. The batteries will, of course, be discharged during the diesel power outage, and it will be necessary to recharge them after restoration of power. The batteries are recharged by increasing the generated voltage of the ac-dc MG set. It will be necessary to shut down the dc-ac MG set during recharge.

When the dc-ac MG set is shutdown, it is possible to supply power for reactor control and instrumentation from the standby transformer. This transformer is energized from the 480 volt commercial bus. The standby transformer is not a reliable source of power for reactor control and will, therefore, not be used during reactor operation.

e. Utility DC Power System

The purpose of the utility dc power system is twofold. First, it supplies power at 250 volts dc for operation of the dc primary emergency coolant pump 670-M-11; and secondly, it supplies power at 250 volts dc for switchgear operation.

The utility dc power system consists of the utility motor generator, a 120-cell, 250-volt battery bank, and the necessary control panels. The utility motor generator is an ac motor driving a dc generator. The ac motor is energized from the 480 volt diesel bus. The 250 volt dc output of the generator is used for switchgear operation, charging the battery bank, and operation of the dc primary emergency coolant pump.

During normal operation, the utility dc motor generator will be supplying power at 250 volts dc for switchgear operation and dc primary emergency coolant pump operation and simultaneously float charging the battery bank. In the event of a diesel power outage, the motor generator will stop. Power will, however, be available from the battery bank for switchgear operation and for operation of the emergency coolant pump. The batteries are capable of operating the dc primary emergency coolant pump for approximately one hour.

After a diesel power outage, it may be necessary to recharge the batteries. This will depend on the length of the outage and the equipment that was operated.

G. Canal Operations

1. Construction

The canal is constructed of reinforced concrete with polyvinyl chloride water stops in the concrete construction joints. The canal is completely lined with stainless steel sheet to the top of the parapet. The parapet rises three feet above the main floor level. The west end of the canal includes provision for westward extension to the proposed hot cell facility.

A vertical lift door in the north wall of the reactor room and over the canal separates the reactor room from the canal area. A bulkhead, mounted on the south face of the door, extends to the bottom of the canal and operates as part of the door. The working canal forms the seal between the door and the bulkhead, thus creating a gastight area on the reactor side. This door and bulkhead will also prevent draining the canal inadvertently in case of an equipment rupture on the reactor side.

The canal is functionally divided into four compartments, the reactor working canal, storage canal, critical facility canal, and the experimenters canal. The canal is approximately 156 feet long and 8 feet wide except for the critical facility canal which is 10 feet wide. The depth of the canal varies; the reactor working area is 45 feet, the area under the ATRC (reactor) is 23 feet, the experimenters section is 39 feet, and the remaining sections are 20 to 22 feet.

A laminated high density glass viewing window is located in the experimenters section of the canal. The total glass thickness plus the water in the insert gives shielding protection equivalent to the 7-foot-thick concrete wall. The dry side of the window is sealed (except when in use) by a steel plate which is designed to withstand full canal water pressure.

A shielded handling cask which mates with the top-head shield is used for transferring the irradiated test assemblies between the reactor and the canal. Spent fuel elements and small irradiated test specimens are passed underwater directly into the canal through the drop tube.

Canal drains are located in the following five sections of the canal: the ATRC side of the storage canal, drop tube in the working canal, experimental area canal, and the experimental pit NE end. There is no drain on the north end of the working canal if the door is down. Each section may be isolated by inserting a water tight bulkhead. Each drain is valved on the outside wall of the canal and connected with the warm waste tank which is located approximately 52 feet below the normal canal water level. If one of the drain valves is inadvertently left open there will be a discharge of canal water to the warm waste tank at a rate of between 1400 and 1600 gpm. Assuming a nearly empty warm waste tank, the tank's high level alarm will sound in the process control room in approximately three minutes, and corrective action can be initiated. With the bulkheads in place and an open drain valve it would take over fourteen minutes to drop the canal water level to the top of any stored fuel elements.

The reactor working canal contains a drop tube located in the 45-foot-deep section and is used for transferring items to and from the reactor. The drop tube will be used when transferring spent fuel, expended control elements, capsule experiments, etc. The remainder of the reactor working canal is 22 feet deep and contains a loop cask transfer station for discharging an experiment from the transfer cask, a loop test assembly storage rack, a pressure tube storage rack, a handling tool rack, and two spent fuel storage racks. The fuel storage racks, with a capacity of 80 elements, will hold spent fuel elements for a short period or until they can be transferred to the normal storage racks in the storage canal. The storage canal contains space for cask storage, irradiated hardware baskets, fuel element storage racks for 140 elements, underwater saw, saw table, a horizontal storage rack for experiment loop pressure tubes, test assembly storage racks, and a handling tool rack with tools. A 39-foot-deep portion is provided at the east end of the canal to permit handling of an entire loop experiment test assembly preparatory to shipment.

Storage space for casks and other equipment is provided on the floor north and south of the storage canal. The live load floor loading for this area is 2000 pounds per square foot.

Truck access to the critical facility is by a rolling steel door in the west wall. Fire walls separate the critical facility area from the storage canal and reactor areas. The critical facility canal may be isolated from the storage canal by a vertical lift fire door and an insulated bulkhead.

The canal area is served by a 30-ton capacity, traveling bridge type crane electrically operated and floor controlled. A 2-ton capacity jib crane, hand crank operated with electric hoist and trolley, is located over the working canal. The primary purpose of the 2-ton crane is to transfer the pressure tubes and test assemblies from the reactor to the working canal. A 15-ton capacity, electrically operated, floor controlled traveling bridge crane is located in the critical facility.

A canal vacuum cleaning device and surface skimmers are used to clean accumulated debris from the canal. Canal drains and vacuum cleaning waste are discharged to the warm waste system.

A portable bridge spanning the storage canal and running on the parapet walls is provided for access across the canal and for canal handling operations. A removable concrete beam is used to support one side to the bridge when crossing the tee portion of the working canal.

The critical facility canal contains a low power operating mock-up of the ATR reactor core where measurements can be made to support fuel element and facility calculations and determine reactivity effects including previously irradiated fuel elements or other components.

2. Operations

The canal is filled with demineralized water and is purged by a continuous makeup and drain of 60 gpm. The water level is normally one foot below the top of the canal parapet. A purge of 60 gpm combined with natural evaporation maintains an average temperature of 85°F based on six spent fuel cores stored in the canal. An insulated bulkhead, normally in position, isolates the critical facility canal which will be maintained at a higher temperature.

Irradiated spent fuel elements are stored in the canal from 90 to 130 days for cooling purposes. After the end boxes have been removed, the elements are transferred out by means of a 15-ton shielded cask. The cask is equipped with a boron poison basket insert sized for nine fuel elements. Water is used as an internal coolant and the outside of the cask has cooling fins.

Under normal operating condition, pH of the water in the canal will be controlled by using sulphuric acid to maintain a pH of 5.5 to 6.5. Samples of canal water will be taken daily and analyzed for chlorides, conductivity, and radioactivity.

3. Emergency Operations

In case of an emergency when the water level in the canal is dropping and cannot be controlled and before the demineralized water supply is exhausted, fire-water should be added from the nearest fire hydrants. When the source of leakage is located, relocate irradiated fuel elements if any and isolate the section using the spare bulkheads.

H. Radiation Protection and Monitoring

1. Shielding

a. General Description

The ATR shielding is designed for a maximum dose rate of 0.25 mrem/hr in full-time occupancy locations. The principal reactor biological shielding consists of ordinary concrete supplemented by three feet of high density concrete opposite the core region and special inserts of lead, steel, and polyethylene in certain locations. The shielding walls of the experimental cubicles consist primarily of high density concrete. The canal walls and floor are composed or ordinary concrete.

b. Reactor Vessel

(1) Nozzle Trench

The shielding around the vessel in the nozzle trench area is designed to restrict the general radiation level in the trench to 12.5 mrem/hr or less, three hours after shutdown. No access is allowed in the nozzle trench during operation. The shielding consists of the two-inch-thick vessel support skirt which surrounds the pressure vessel and extends from the floor of the capsule trench to the four-inch vessel wall section.

(2) Top-Head Shield

The concrete in the working platform is 12 inches thick and is designed to restrict the dose rate at its upper surface to 1.0 mrem/hr or less during normal full power operation. The shield cylinder is sized to restrict the transient dose rate during specimen transfer to 1 rem/hr or less at the shield surface. The cylinder shielding is composed of three inches of steel and nine inches of lead. During operation, the dose rate at the shield cylinder surface is computed to be less than 1.0 mrem/hr. The design of the loop transfer shield plate is based on the same criteria as those for the shield cylinder, and results in a shielding thickness of 15 inches of steel. The top-head ring shield is composed of four inches of lead, two inches of steel, and is designed to reduce the dose rate around the top-head area to less than 1.0 mrem/hr during normal full power operation.

(3) Primary Biological Shield

The reactor vessel is surrounded by a composite shield which includes three feet of high-density magnetite concrete, two and one-half feet of structural concrete, and five and one-half feet of ordinary concrete. The concrete completely surrounds the vessel except in the area shielded by the working canal water. One hour after shutdown, the dose rate in the piping corridor from sources within the reactor vessel is calculated to be less than 1 mrem/hr. A three-foot thickness of magnetite concrete shielding separates the nozzle trench from the reactor floor area.

The pipe corridor, which contains the primary and test loop piping, separates the two and one-half feet thick and five and one-half feet thick sections of primary shield. At full power, the dose rate from N-16 at the outer surface of this shield is calculated to be 6 mrem/hr. The dose rate from the operating core is negligible.

c. Primary System Shielding

(1) Coolant Loop Shielding

The primary coolant piping is shielded by a minimum of five and one-half feet of ordinary concrete. The maximum dose rate at the outer surface of this shield is calculated to be 6 mrem/hr. The walls around the heat exchanger room are of the same dimensions with a maximum dose rate of 6 mrem/hr at the outer shield surface. The floor above the heat exchanger room is six feet of ordinary concrete. The maximum dose rate at the floor surface is computed to be 1.5 mrem/hr.

(2) Primary Pump Cubicles

The wall between the pump cubicles and heat exchanger area is five and one-half feet of ordinary concrete. This reduces the radiation level from sources in the heat exchanger room to 2.5 mrem/hr in the pump cubicle. The walls between the pump cubicles are four feet thick and the calculated dose rate in any cubicle from an adjacent cubicle is 7 mrem/hr. The exterior walls of the pump cubicles are also four feet thick with a resulting dose rate of 7 mrem/hr in the motor area.

d. Subpile and Rod Access Rooms

The subpile room is shielded from the core by 10 feet of water in the reactor vessel and by the one foot thick vessel bottom head. One hour after shutdown, the dose rate from the core through this shielding is computed to be less than 1 mrem/hr. The wall between the working canal and the subpile room consists of four feet of ordinary concrete. This wall is designed to limit the dose rate from a spent fuel element stored in the deep end of the canal to 7.5 mrem/hr in the subpile room. The steel door in the subpile room is 10 inches thick and is sized for a dose rate outside the door of 2.5 mrem/hr.

Three feet of concrete, four inches of steel, and six inches of polyethylene shield the rod access room from the core radiation and from N-16 in the test loops. Dose rates from these sources were computed to be less than 2 mrem/hr in the rod access room during full power operation. Where the test loop traps and exit piping are imbedded in the subpile room floor, the concrete is replaced by 6.5 inches of lead below the piping and 7.5 inches below the trap. The polyethylene is required below the lead and steel to ensure adequate attenuation of the neutrons from N-17 in the test loop coolant. The magnetite concrete wall between the piping corridor and the rod access room is three feet, eight inches thick. The maximum dose rate in the rod access room is 8 mrem/hr. The total dose rate from all sources is less than 10 mrem/hr.

e. Canal Shielding

The canal bottom below the fuel element storage racks is seven feet of ordinary concrete. The dose rate below this floor is less than 1.0 mrem/hr. Where the canal floor passes over the experimental cubicles, 5.5 feet of ordinary concrete is used, leading to a dose rate of 5.0 mrem/hr in the cubicles. Seven feet of ordinary concrete is provided for the lower portion of the canal walls, with resulting dose rates at the outer surface of the shields less than 1.0 mrem/hr.

f. Experimental Loop Cubicles

The walls and floors between cubicles are sized for a dose rate of 2.5 mrem/hr inside a cubicle (with test loop shutdown) from an adjacent operating cubicle. The walls are constructed of magnetite concrete blocks and are two feet, eight inches thick. The floors consist of four feet, six inches of ordinary concrete. The cubicle ceilings in the first basement are made of ordinary concrete, five feet in thickness, in order to meet the 1.0 mrem/hr design level on the reactor floor.

g. Demineralizer Vaults

The vaults are shielded by three feet, six inches of concrete block followed by a valve corridor of three feet, six inches and a final eight-inch concrete protective wall surrounding the valve corridor. The hatch covers in the floor above the vault consist of five feet, six inches of concrete. The dose rates from the resin beds at the areas adjacent to the walls and ceilings of the vaults are variable and are, therefore, under administrative control.

h. Radiation Control Areas

Shielding for certain areas has been provided for limited access during particular periods of the overall operation. It is uneconomical to provide shielding in these areas to cover all eventualities. These areas are placed under administrative control with respect to entry procedures and times of access. A list of these areas together with possible radiation sources is shown in Table IV. Table V is a summary of calculated dose rates in these areas.

TABLE IV

ATR RADIATION CONTROL AREAS

Location	Operation	Radiation Source
Nozzle access trench	Removal of instruments and irradiated capsules	Streaming through instrument wells and capsule penetrations, activated capsules
Subpile room	Experiment loop removal, general maintenance	Contaminated experiment loops, streaming through in-pile loop penetrations, spent fuel elements passing through transfer chute
Pipe corridor	Maintenance on rod drive mechanisms	Contaminated experiment loops, spent fuel passing through transfer chute
Experiment loop test cubicles	Maintenance on test loop equipment	Contaminated test loops
Reactor area, first floor	Removal of activated loop components	Streaming out of top and bottom of transfer cask
Reactor top-head area, top-head shield removal	Spent fuel removal, general maintenance	Contaminated experiment loops, raised fuel elements
Top-head shield, & transfer station	Transfer of test specimen	Test specimen
Demineralizer vault areas	Change out of resin	Fission products and activated crud

TABLE V

SUMMARY OF CALCULATED DOSE RATES IN ATR RADIATION CONTROL AREAS

Location	Maximum Calculated Dose Rate During Full Power Operation (mrem/hr)	Maximum Calculated Dose Rate After Shutdown (mrem/hr)
Outside reactor concrete shield	6.0	< 1.0
Outside experiment H_2O loop cubicles (N-16 activity only)	2.5	< 1.0
Inside experiment H_2O loop	5.0 from adjacent operating cubicles (N-16 only); 6.0 from reactor and primary piping	< 1.0
Subpile room	No access	1 from core through vessel bottom head (does not include streaming through bottom-head penetrations)
Rod access room	10.0	< 2.5
Floor above heat exchangers	1.5	< 1.0
Reactor area, first floor	1.0	< 1.0 except during specimen and loop component transfer
Reactor vessel top head	1.0	< 1.0 except during specimen and loop component transfer. < 25 during fuel transfer
Above storage canal and at floor level near parapet	1.0	1.0
Above storage canal during spent fuel transfer	50.0 transient	50.0 transient
Below storage canal		1.0
Outside walls of storage canal	1.0	1.0
Outside pipe tunnel	6.0	≤ 1.0
Motor area outside pump cubicles	7.0	< 1.0
Inside pump cubicles	4.0 from heat exchangers and piping, 7.0 from adjacent pump cubicle	
Nozzle access trench	No access	12.5 from core and stored fuel (does not include streaming through vessel penetrations)
Office areas	< 0.25	< 0.25 except during specimen and loop component transfer

2. Radiation Monitoring System

a. General Description

The purpose of the ATR radiation monitoring system is to detect, indicate, and record radiation levels at selected points throughout the ATR facility. At preset radiation levels alarms are activated. Interlock relays are provided to control certain ventilation equipment at preset high radiation levels. The ATR radiation monitoring system is composed of 36 beta-gamma area and process monitors, 23 airborne particulate monitors, 17 portal monitors, 3 hand and foot monitors, a stack monitoring system, 3 ruptured fuel element monitors, and 4 interlock relays. All components of the system alarm on both the Health Physics monitoring panel and the reactor control panel.

b. Beta-Gamma Area and Process Monitors

The beta-gamma area and process monitors detect direct beta-gamma radiation in the ATR plant area. Each channel operates as a GM tube feeding the indicating meter by means of a ratemeter at low intensities and as an ionization chamber feeding the indicating meter a direct current as the GM pulse output saturates at high intensities. In the event of abnormal operation, when fields exceed 5000 R/hr, the ionization current of the sensor tube is sufficient to drive and hold the meter at full scale and in alarm condition without any current from the ratemeter circuit.

Power for the operation of the 37 detectors is supplied from the Health Physics monitoring panel. The detectors are connected to 8 separate power supplies on the HP panel so that a power supply failure will not leave an entire area of the plant without monitoring and so that no more than one interlock function will be lost per failure.

The detectors of Channels 1 through 29 drive local meters and visible and audible alarms. Power for these alarms is supplied from either the detector or its power supply without recourse to local ac power supplies. The local meter-visible alarm units for Channels 30 through 37 are mounted on the process control panel. Power for the "acknowledge button" for these channels is taken from a source on the process control panel. Alarm signals from any of the 37 channels actuate an annunciator on the reactor control room panel. Recorders and station indicators for each detector are mounted on the Health Physics monitoring panel.

On all 37 channels, the alarms are actuated by meters such that when the reading exceeds the setpoint of the fully adjustable meter relay the following alarm sequence is actuated:

(1) An alarm light at each station indicator and an alarm bell and light on the associated power supply.

(2) A light and a bell at each remote indicator.

(3) Reactor control room annunciator #8.

(4) Automatic shutoff of the alarm lights, bells, annunciator contacts, and interlock signals shall be provided except for the station indicator light (located on the Health Physics monitoring panel), which remains lit to provide "memory" when the radiation level falls below the preset level.

(5) Channels GM 2, 5, 6, 23, 24, 25, 34, and 35 are provided with fully adjustable trip points which actuate interlocking relays with the heating and ventilating system. These trip points operate at higher levels of radiation than the meter relay alarm points and are completely independent of them.

(6) All contacts open to alarm, interlock, annunciate, or warn of low power.

c. Airborne Particulate Monitors

The 23 cart-mounted airborne particulate monitors utilize end window GM detectors to detect the presence of radioactive particulates in the plant air. Each monitor has an automatic range change ratemeter with linear ranges of 0-2000, 0-10,000 and 0-20,000 counts per minute. The ratemeter is equipped with a non-overloading safety device to prevent the lack of pulses from a completely saturated tube from appearing as a low count rate.

Six carts (Channels 1 through 6) are equipped as mobile units with recorders so that they may be positioned at any location in the plant. Channels 7 through 23 are equipped for remote recording on the Health Physics monitoring panel and remain in stationary locations. Power for the recorders for the 17 stationary carts is obtained from a fused power panel on the Health Physics monitoring panel.

The alarm sequence for the 23 airborne particulate monitors is as follows:

(1) When a change from the 2K to the 10K range occurs, the amber light will burn continuously for 12 to 15 seconds and then start to flash on a 2 to 5 second cycle. The bell will ring for 12 to 15 seconds and then go silent.

(2) When a change from the 10K to the 20K range occurs, the red alarm light will start flashing on and off on a 2 to 5 second cycle and will continue to do so until the count ratemeter changes scales. The bell will simultaneously start to ring intermittently on a 2 to 5 second cycle and will continue to ring in this manner until the count ratemeter changes scales or the bell is silenced by the bell interrupter switch.

(3) All alarms are annunciated on the Health Physics monitoring panel. High level alarms are annunciated on the reactor control panel.

(4) Interlock actuations controlled by the CAM units are produced by the electronic trip point of the DeVar recorders mounted

in the Health Physics monitoring panel in conjunction with the repeat relay controlled by the high level window of the annunciator.

d. Hand and Foot Monitors

Three hand and foot monitors are located in the ATR plant area. Each monitor is a completely integrated system providing detection of beta-gamma contamination of the hands and feet. Each unit consists of a pedestal-mounted cabinet with foot deck and hand cavities.

Each unit has an individual ratemeter for each hand and each foot. A fifth ratemeter is provided for an external probe which can be used for monitoring the head or clothing of personnel. An alarm light for high activity is provided for each individual channel. Alarms automatically reset after 10 seconds. An audible alarm for high activity is provided by a high frequency buzzer. A loud speaker with variable volume control annunciates the clicks from all channels. The counting range of each channel is adjustable from 0-500, 0-2000, 0-5000, and 0-20,000 counts per minute.

e. Portal Monitors

The portal monitors installed in the ATR facility automatically compensate for changes in the existing radiation background of the area. An abrupt change in the count rate, such as that caused by a contaminated person passing near the monitor, is quickly detected and alarmed. The positions of the portal monitors were selected so that all personnel will pass through a portal monitor whenever leaving a potentially radioactive area.

Each portal monitor unit contains 11 GM detectors. With two exceptions, four tubes are positioned on each side of the unit, one overhead, and two in the floor. PM-8 has three detectors on each side, three in the floor, and two overhead; PM-12 has seven detectors positioned in the floor and four detectors positioned along the west side of the doorway.

f. Stack Monitoring System

(1) Location

The stack monitoring system is located outside the fan room in the northwest corner of the second basement. Recorders connected with this system are located on the Health Physics monitoring panel and on the reactor control room instrument panel.

(2) Description

The stack gas is sampled by an isokinetic nozzle 50 feet downstream in the underground portion of the stack duct through a two-inch stainless steel sampling line. A flow divider located in the second basement provides a sampling valve so that the gas can flow through one-inch stainless steel lines to both the stack monitoring system and to the sample port or through the stack monitoring system only. The sample port is valved to permit a gas sample to be taken for spectral or other analyses. The one-inch line leading to the monitoring system first goes through a tracer lab filter tape transport for continuous particulate monitoring. The filter drive mechanism is a solid perforated capstan which limits the air bypass around the filter tape to < 2 percent. The standard speed of the filter paper advance is 1 inch/hr, and a regular spool of gauze-backed HV-70 filter paper provides approximately 25 days of continuous usage. Alarms are provided to indicate lack of paper and a tear in paper. The particulate activity is monitored first by an MD-5B Gamma Scintillation Detector Assembly and then by an MD-3B Alpha Scintillation Detector which is placed six inches downstream of the sampled area to allow for a six-hour decay of the short-lived, natural occurring radon and thoron daughter products.

From the particulate monitors the gas sample passes to a Tracerlab Model MG-1A Gaseous Monitor which contains a gamma scintillation detector. From here the sample flows through a charcoal filter to effect iodine removal and then through a Tracerlab Model MX-14C pumping system equipped with a muffler and a Magnahelix flow indicator. The gas will then flow through a pressure reducing orifice to a valving arrangement whereby the sample may be directed either to the stack or through a delay tank (two minute delay for 10 cfm flow) to a gamma particulate monitor and a pumping system similar to the ones mentioned above. The delay allows a portion of the noble gas activities present to decay and form particulate daughters. Since the daughters of the fission product noble gases are radioactive while the daughter of Argon-41 is not, a determination can be made of the gaseous activity measured previously that was due to fission products. The sample will then be exhausted to the stack.

g. Ruptured Fuel Element Monitors

(1) Iodine Fission Break Monitor

The iodine fission break monitor is designed to detect releases of significant radioactive iodine fission products into the primary coolant system from a ruptured fuel element or experimental fuel capsule.

The detector equipment is located in a cabinet in the waste tank motor area below the second basement level with a recorder and annunciator located in the reactor control room and on the Health Physics monitoring panel in the Health Physics office.

A metered flow of primary coolant water is drawn from the outlet line of the primary coolant cation demineralizer header, through pipe corridors to the bottom of the sample cabinet, then through a glass wool filter and an anion resin column, and is discharged to the warm waste tank directly below the motor area. A low flow annunciator is located on the Health Physics monitoring panel.

A scintillation detector is positioned by the anion resin column to monitor the concentrated iodine activity collected on the anion resin. This detector is operated with a discriminator setting of about 0.8 MeV to bias out activity from Cr-51 and Mo-99 radicals which also concentrate in the anion column. The higher radiations are predominantly iodine. The distance between the detector and the anion column can be varied to keep the instrument on the proper scale.

(2) Fast Fission Break Monitors

Two fission break monitoring channels are provided to immediately detect a release of fission products into the primary coolant system. Each channel consists of a gamma ionization chamber, a microammeter, and a recorder. The detectors are located at the primary system outlet piping header with the electronics housed in a cabinet located in the 1A experimental cubicle sample corridor. Delay time is several seconds. Two microammeters are located on the Health Physics monitoring panel in the Health Physics office, and two recorders are located in the reactor control room. Each location also has an annunciator.

h. Interlock Relays for Heating and Ventilation System

Located on the Health Physics monitoring panel are four interlock relays for the purpose of actuating interlocks with the heating and ventilating system. The purpose of these interlocks is to control the release of airborne contamination to the environs in the event of a serious unplanned event at the ATR. These relays open to perform the interlock action and have contacts to actuate two indicating lights (one on the Health Physics monitoring panel and the other in the reactor control room). The interlock relays will reactuate if they are reset while an activating condition still exists. The interlocks may be positively overridden by means of a pushbutton located at the emergency diesel start-up panel. All input signals to the interlock relays that do not require a coincidence for actuation are provided with test blocks on the Health Physics monitoring panel which enables calibration and testing without shutting off the ventilation system.

Interlock relay number 1 is actuated by a high radiation signal from either the stack breech monitor (GM 34) or from the exhaust plenum monitor (GM 35). When interlock relay number 1 opens, the following occurs:

(1) The stack breeching damper closes.

(2) Main exhaust fans HVE-17A and HVE-17B shut off.

(3) The following equipment associated with the reactor area supply system shuts off:

(a) HVS-1 and three associated butterfly dampers

(b) HVR-1 butterfly damper

(c) NVS-4 two butterfly dampers

(d) HVS-5 two butterfly dampers

(e) NVE-9 and one butterfly damper

(f) HVA-2 and three associated butterfly dampers

(g) HVE-4

Interlock relay number 2 is actuated by any one of the following:

(1) A concidence of interlock signals from CAM 7 and CAM 14 located in the reactor room.

(2) A two-out-of-three coincidence of GM 2, GM 5, and GM 6 which surround the reactor.

(3) A two-out-of-three coincidence of GM 23, GM 24, and GM 25 located in the second basement.

When interlock relay number 2 opens, the reactor area supply systems are again shut off as shown for interlock relay number 1 (3) above, and the exhaust from NVE-1 is routed to the main exhaust plenum by means of two dampers.

Interlock relay number 3 is actuated by the ATRC airborne particulate monitor (CAM 10) or by the beta-gamma area monitor (GM-5). When this relay opens, the ATRC supply system (HVS-2) and associated dampers are shut off.

Interlock relay number 4 is actuated by either CAM 8 or CAM 9 which monitor the canal. When this relay is opened, the storage canal ventilation system (HVS-3) is shut off along with the associated monitor-operated dampers and roof ventilators.

I. Miscellaneous Radiological Hazards

1. General

In the operation of a test reactor there are a number of minor incidents which constitute a radiological hazard within the plant, yet do not present a significant environmental hazard. Dependence must be placed on the radiation monitoring equipment and administrative procedures for the control of these hazards and the protection of personnel. These accidents can be grouped as follows: (1) fission breaks into the primary coolant, (2) fission breaks into the experiment loop coolant, (3) releases of radioactive gases into the building air, and (4) release of solid or liquid radioactive materials into the building.

2. Fission Breaks Into the Primary Coolant

During the operation of the reactor, there may be occasional periods when the primary coolant will be contaminated with fission products from defective fuel elements or experiments. The resulting radiological hazard is limited by the integrity of the primary system and its shielding.. The ATR shielding will limit the radiation level to about 5 mrem per hour, for a release of all the fission product inventory of one fuel element (after 16 days operation) uniformly distributed in the primary system.

When the primary system becomes contaminated, the Fission Break Monitor will detect the increased activity. Additional indication of the radiation level is provided by a monitor on the degassing tank exhaust line. Alarm signals from the radiation monitoring system will alert the operator to take the necessary steps to prevent excessive exposure of personnel.

If the contamination is from small fission breaks, the radiation level outside the shielding will not increase significantly; however, shutting down the reactor will in any event reduce the amount of activity released.

The contamination can be removed from the primary system by demineralizing, controlled degassing, and then by flushing prior to removing the damaged elements or experiments.

3. Fission Breaks Into Experiment Loop Coolant

Experimental programs that are intended to develop improved fuel materials often require operation up to or beyond specimen failure. The failure of a specimen will contaminate the test loop coolant with fission products and require the safe disposal of radioactive liquids and gases.

The shielding around the pressurized water loop cubicles will limit the radiation level outside the cubicle after an experiment failure. A specimen failure (previously described) results in a one-hour integrated dose outside the cubicle of about 12 mrem.

The pressurized water loops have integral ion exchange units for cleaning up contaminated coolant. The loops may be drained, vented, and flushed through a closed system to shielded waste collection tanks. The loops may be chemically decontaminated if necessary.

The gas-cooled loop, which has not yet been designed, will be provided with a suitable gas cleanup, holdup, and vent system as required for the disposal of the waste gas from the closed loop.

4. Release of Radioactive Gas Into The Building Air

The release of activity into the ATR building air from normal operation is limited by maintaining the vent and drain systems under continuous suction and design of air flow patterns to prevent backflow of contamination. At MTR and ETR, minor releases of radioactive gases into the building air have occurred in the operating history and must be considered for ATR. Radiolytical gas releases have occurred in the MTR and ETR. Although some of these releases have interferred with operation, they did not constitute a major hazard. In a number of cases, the evacuation of the entire reactor building has been required, but usually only parts of the building required isolation. In a very few cases, the atmospheric conditions permitted contaminated stack discharge air from one reactor to enter the neighboring reactor building and required its evacuation.

The radiation monitoring equipment in the ATR building will detect air contamination and sound the appropriate alarm. The radiation monitoring system will also isolate certain building areas by shutting off ventilation. If the radiation or air contamination levels exceed safe limits, the reactor will be scrammed and the planned ATR evacuation procedure instituted.

5. Release of Solid or Liquid Radioactive Materials Into The Building

Spillage accidents at MTR and ETR usually involve minor leakage of reactor or experiment coolants. While not usually a serious radiation hazard in themselves, these spillages may contaminate the building air. Under such conditions monitors will sound an alarm and appropriate safety measures can be taken. The reactor cooling system and the experiment cooling systems are designed, fabricated, and tested to assure maximum integrity. Consequently, spillage accidents are expected to be only minor nuisances. Furthermore, all floor areas include ample drains connected to the waste tanks which provide for spillage runoff and permit immediate washdown. The waste tanks and the drains are vented to the waste gas system. This provides a continuous flow of sweep air for positive removal of airborne activity.

J. Environmental Hazards Associated With Normal Operation

During normal operation the ATR will produce radioactive gaseous effluents which are vented to the stack. These effluents are variable in concentration and quantity. A review of the operating history of ETR is used to evaluate the acceptability of the ATR effluent.

During 1959, when a large open cycle air-cooled experiment was operating in ETR, its stack gas effluent carried up to 5 curies per megawatt-day or a total of 875 curies per day. An open cycle air-cooled experiment is not planned for ATR. The calculated normal gas effluent at ATR is expected to be 40 curies per day of Kr and Xe. The argon-41 activity produced from shield cooling is negligible.

Air monitor readings in the ETR building are correlated with releases of activity from the ETR stack in IDO-16623. The data indicate that an ETR stack release of 875 curies per day would result in a maximum specific activity of 1.6×10^{-9} curies per cubic meter in the ETR building. The records indicate that this specific activity was exceeded only 2.4 percent of the time that the stack discharge averaged 875 curies per day. The corresponding value of the maximum specific activity during normal operation of the ATR is expected to be only 0.075×10^{-9} curies per cubic meter. In view of the more favorable location of the ATR stack with respect to the three reactor buildings, the expiated maximum specific activity and its frequency of occurrence in any of the three buildings as a result of ATR operation should be substantially less than the levels produced by the ETR.

In any event, the expected level is significantly less than 4×10^{-9} curies per cubic meter permitted in National Bureau of Standards Handbook No. 69 for a 40-hour week continuous exposure to mixed beta-gamma activity, and a factor of 10^{-4} below the permissible specific activity for the noble gases. Hence, there is expected to be no significant environmental hazard from the normal operation of ATR.

K. Environmental Hazards Associated With Large Releases of Radioactivity

1. General

The environmental hazard associated with accidents leading to large releases of radioactivity has been analyzed. The results are presented in this section. All computations are based on building leakage at the rate of 10 percent of the building volume per day.

The fission product release assumed for the calculations is based upon a major accident hypothesized for purposes of site analysis and postulated from consideration of possible accidental events that would result in potential hazards not exceeded by those from any accident considered credible.

2. Fuel Transfer Accidents

An operational accident can result in the release of the fission products in any single fueled component. The largest fueled component is a single fuel element which contains 3 percent of the total core fission product inventory. In the analysis of the fuel transfer accident, it is assumed that the released fission products are distributed immediately throughout the air in the gas-tight volume of the building. The environmental hazard results from direct radiation from the contaminated air in the superstructure and the leakage of the air from the building. Although short term leak rates greater than 10 percent per day occur, dose rates to off-site areas are based on long term average values. Dose rates to TRA personnel are based on short term adverse weather that will not result in an average leak rate of 10 percent per day. The unknown factor of time required to disperse fission products uniformly in the superstructure also will reduce short term fission product release rate. Based on these factors, an average leak rate of 10 percent per day was used in the calculations.

In melting one fuel element, the fission products released are 3 percent of the quantities shown in part 10 CFR-100 (Code of Federal Regulations). This accident releases the following percentages of the core fission product inventory after 17 days of operation at 250 MW: (a) 3.0 percent of the rare gases, (b) 1.5 percent of the halogens, half of which are assumed to be absorbed on building and equipment, and (c) 0.03 percent of the solid fission products.

During the course of the fission product release, the fission products in the building are assumed to undergo radioactive decay. No credit is taken for decay in the plume en route, for fallout, nor for rainout. These assumptions are in accordance with the recommendations in 10 CFR-100.

The results calculated for this accident are believed to be conservative for the following reasons: (a) fuel melting will not occur instantaneously, (b) the fission products will not be distributed immediately throughout the superstructure, and (c) the fission product inventory is conservatively high since a minimum of five hours decay after shutdown is required before transferring fuel.

L. Coupling by Direct Radiation During Normal Operation

1. Coupling Through Common Facilities

The direct radiation from one reactor facility to the other at the MTR-ETR site has resulted in shutdown when the area radiation monitors of one plant responded to sources in the other. This has been an operational inconvenience. The relatively greater separation of the ATR from the other TRA facilities will reduce possible coupling by direct radiation.

The MTR, ETR, and ATR share a number of common auxiliary systems and facilities. Since the initial installation of the MTR, these systems have been augmented with parallel equipment and transfer facilities to satisfy the requirements and to ensure dependable service to the MTR, ETR, and ATR. The ATR is designed so that a failure of an interconnected system from causes associated with the ATR will result in little or no disturbance to the other reactors. However, a gross failure of any system if not corrected within a reasonable time will cause all reactors to shutdown. All reactors are designed to be shutdown safely if the failure of any system is not corrected in time. These failures would not depend on the proximity or coupling of the ATR.

Systems used by the ATR that are common to all reactors in the complex are divided into two parts: those indirectly affecting reactor operations and those directly affecting reactor operations.

2. Common Systems Indirectly Affecting Reactor Operations

The three reactors are served by the following common systems whose failure at the ATR would indirectly affect reactor operations: (a) chemical systems, (b) diesel oil storage, (c) potable water system, (d) heating steam and condensate, (e) liquid waste disposal, and (f) communications.

The failure at the ATR of one of the above systems would not immediately effect any reactor operations, but might over a period of time, if uncorrected, force the operators to shut down the ATR and in some cases the other reactors. In the case of all pipe ruptures, adequate valving is available to isolate the severed pipe.

(a) Chemical Storage

All chemicals handled at the ATR are from individually sealed containers or tanks with the exception of the sulfuric acid which is pumped from one of two MTR acid storage tanks to the Cooling Tower Pump House. An accident involving the ATR chemical systems would provide only a local problem for the ATR operators, but it would not necessarily affect any reactor operation.

The effect of chlorine gas escaping from one of the two storage bottles in the ATR Cooling Tower Pump House, which is located north of the ATR Reactor Building and northwest of the MTR-ETR area, has been analyzed, and it was concluded that this accident will not endanger any personnel on the site. Meteorological coupling data, the dilution effects of the atmosphere, and the location of the bottles in a separate enclosed room with only one door facing west was considered in reaching the above conclusion.

b. Diesel Oil Storage

A rupture of the diesel oil supply line to the day tank, ATR-775, would not effect operation at the MTR or ETR since each facility has a sufficient supply of diesel oil in the day tanks (minimum tank capacity of eights hours supply) to ensure continued operation. The transfer pumps located in MTR-627 building would still be capable of delivering diesel oil to the other day tanks after the ruptured line is valved off by the operators. It is reasonable to assume, considering the time available from diesel oil storage in day tanks, that the operators can valve off any line break in a few hours. The other plants would not be affected by a line break at the ATR. A rupture of the diesel fuel oil line to the ATR diesel engines would force the shutdown of the ATR but would not affect the other reactors.

c. Potable Water System

The loss of potable water to the ATR will not affect the operations of the MTR and the ETR reactors but will inconvenience the operators. However, since potable water is used for the ATR diesel-engine jacket-water makeup, the loss of this service over a period of time will cause the shutdown of the ATR diesel engine generators, and, thus, the ATR reactor. Similarly, if potable water is used for makeup service in the MTR and ETR auxiliaries, then these plants may also be similarly affected if potable water is lost site wide.

d. Heating Steam and Condensate

The steam plant is capable of supplying the requirements of all three reactor plants, and the loss of any supply or return line to or from the ATR will not effect the MTR or ETR plants. The loss of steam or consensate return lines to the ATR will inconvenience the operators due to the loss of the heating system, but will not affect the operation of the ATR reactor.

e. Liquid Waste Disposal

Interruption of the liquid waste disposal system in the ATR will not affect the operation of the MTR and ETR in any way since the waste storage and disposal systems are designed to handle all three plants. On loss of the warm waste system, the ATR operators can also take action to restrict any noncritical warm drains including floor drains which are fitted with covers. However, the prolonged loss of the use of the ATR warm waste system will affect the operation of the ATR reactor since the gland seals and N-16 monitor water, which are necessary for continued operation of the ATR, drain to the warm waste tank.

f. Communications

The ATR communication facilities consist of three separate systems. Of these only the telephone and code call systems are interconnected with the MTR and ETR systems.

g. Summary

The ATR building and stack have been located to use prevailing wind patterns to minimize releasing or receiving radioactive airborne material to and from the MTR-ETR area. The ATR distance from the MTR-ETR area makes direct radiation hazards between areas a remote possibility. Supplementary equipment installed in auxiliary systems common to the three reactors has increased system reliability. New and existing piping systems have been designed with shutoff protection in the event of localized failure. Electrical systems are designed to isolate faulted areas.

Based on the above factors, it is concluded that the addition of the ATR does not represent a significant increase in hazards to the TRA area during normal operation. Failures in systems common to all reactors do not represent a safety problem to any of the reactors, but may require one or more reactor shutdowns.

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CHAPTER V

THE IDAHO CHEMICAL PROCESSING PLANT

The Idaho Chemical Processing Plant (ICPP) was designed and built under the direction of Oak Ridge National Laboratories, Oak Ridge, Tennessee. Construction was completed in 1952, and it started operation in the spring of 1953. The original engineer's estimate was 28 million dollars. The plant has since been modified and improved, and it is presently valued around 68 million dollars. The original purpose of the ICPP was to demonstrate on a full scale basis the feasibility of recovering U-235 from spent reactor fuel. It has been used as a production plant for this same purpose for the past ten years.

When built, the ICPP was unique. It was the first and only plant designed for direct maintenance; that is for maintenance work to be done on the equipment in place with conventional tools rather than using special remote handling tools. Most other chemical processing plants in the atomic energy field were designed for remote maintenance. Because of the success of the ICPP, many other plants, more recently built, have used the direct maintenance philosophy.

At the present time nearly all types of enriched reactor fuel can be processed at the ICPP. At some future date it is possible that low enriched elements will also be processed and the plutonium salvaged as well as the uranium. There is now no partitive equipment in the plant which would allow the Pu to be separated from the waste stream.

A. Fuels Processed

The ICPP can recover uranium from three basic types of reactor fuel elements: aluminum clad, zirconium clad, and stainless steel. The aluminum clad fuel elements are processed in the greatest numbers and are the easiest to process. Zirconium clad fuel elements, from the naval reactors and some other sources, and the stainless steel clad elements are a little more difficult to process. The potential capacity of the plant is over six MTR cores per day for aluminum fuel but a little less for the others.

B. Basic Methods of Recovery

The first step in reclaiming the uranium from fuel elements is to dissolve the fuel in one or more acids. The next step is to separate the uranium from the fission products and structural material by solvent extraction. The solvents used are organic material, hexone (methyl-isobutyl-ketone), and TBP (tributyl phosphate). The plant product is uranium nitrate which is concentrated, bottled, and shipped to Oak Ridge Laboratories where the uranium is extracted and refabricated into reactor fuel.

The basic concept of direct maintenance requires that each step in the process be housed in its own special compartment so that only one section need be decontaminated for repairs at a time. These compartments, called cells, are shielded from each other by concrete walls.

Figure 42 shows the plant layout. The dissolver cells are located on the west side of the plant. Cells A, B, C, and D contain the batch dissolver equipment, some of the original equipment installed in the plant. Cells E and F contain batch process equipment for dissolving zirconium and stainless steel fuel elements. Cells G and H contain the continuous dissolution system for aluminum fuels and the first step in uranium extraction. This system has a very large capacity as compared with the others. Cell J is a uranium salvage cell. Cell K is a solvent recovery cell, and cell Z is the final product storage cell.

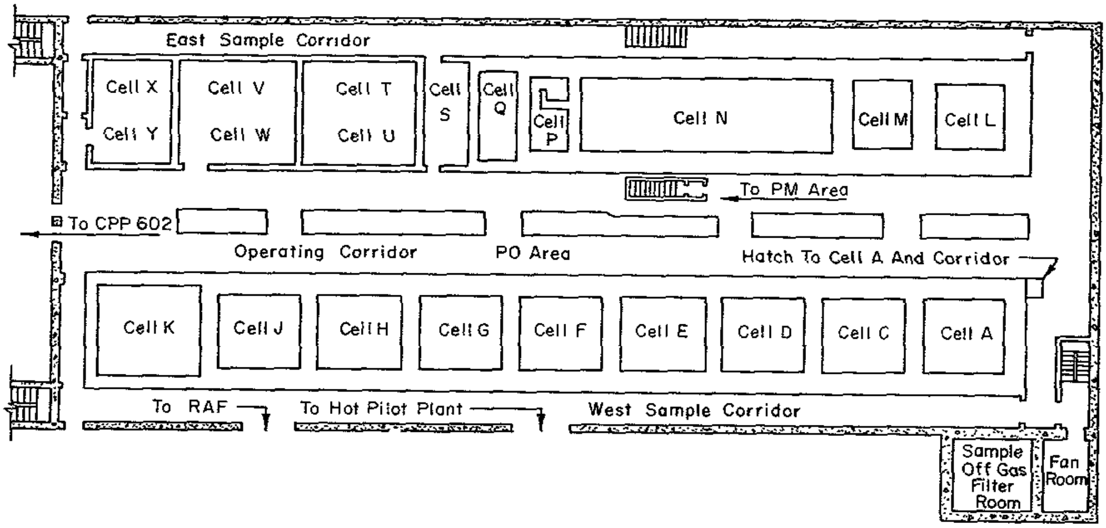

Figure 42

Idaho Chemical Processing Plant Layout

On the east side of the plant are the extraction cells. N cell is the feed storage cell*. Cells P, Q, and S house the first, second, and third cycle extraction equipment. Cells U, W, and Y are waste treatment and storage cells. Cell L was used for the RaLa process described later in the chapter. The laboratories and utilities supply facilities are located in the north section of the plant.

1. The Batch Process

The aluminum batch process, the oldest system in the plant, has a very limited capacity. Presently, it is not being used for anything but special projects. The dissolution is carried out in cells C and D and is accomplished by adding nitric acid to a dissolver vessel along with the catalyst, mercuric nitrate, and charging it with fuel elements through a chute from the Process Makeup Area. After the elements have been dissolved, the feed is filtered

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* Feed is the product of the dissolvers and contains uranium, structural material, and fission products in solution. It is the feed stock for the extraction columns.

and adjusted as to pH. It is then transferred to N cell for temporary storage. The storage in N cell acts to smooth out the flow through the plant. Figure 43 is a simplified flow sheet on this process.

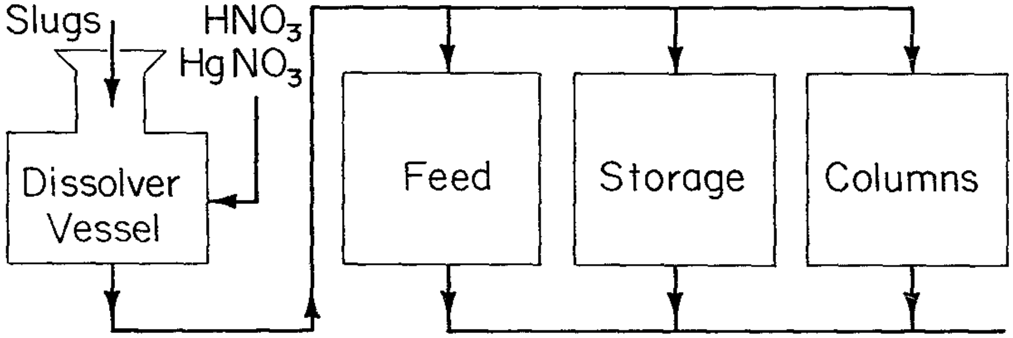

Figure 43

ICPP Aluminum Batch Process Flow Diagram

Figure 44 is a simplified flow sheet of the extraction system. It is a continuous process depending on the solubility of uranium in hexone or in water according to the concentration of the nitrate ion in solution. In P cell the first cycle of extraction is carried out in a long column packed with one quarter inch stainless steel raschig rings*. The feed material enters the column near the center. Hexone enters the column near the bottom. The difference in density causes the two solutions to flow counter current. In a high concentration of nitrate, the uranium is more soluble in hexone than in water, and

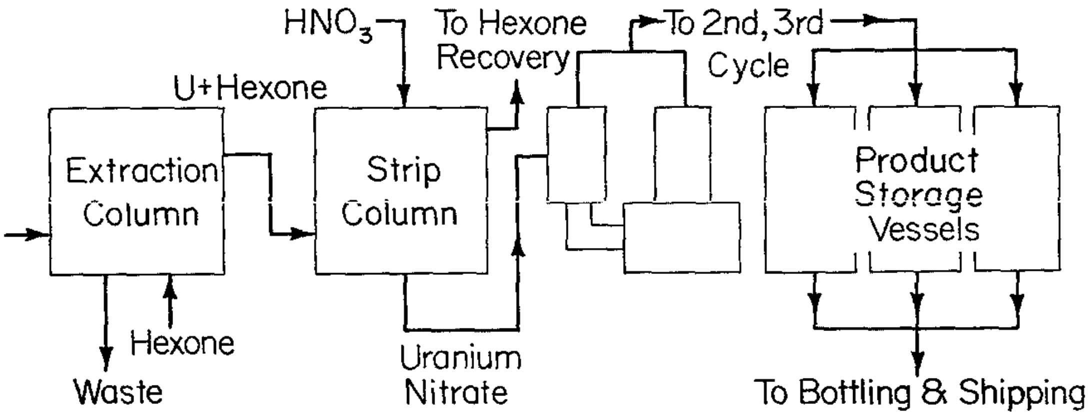

Figure 44

ICPP Aluminum Batch Process Extraction System Flow Diagram

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* A raschig ring is a piece of tubing with the same length as diameter. It is used to break up the flow of liquids in the column and assures good mixing of the two materials.

therefore, the solvent contains the uranium when it exits near the top. The water exits the column near the bottom carrying with it the fission products and other waste material. Aluminum nitrate is added to the column feed to act as a scrubber, to insure that all of the uranium is carried over in the hexone. The uranium is then back-extracted into dilute nitric acid in a stripping column. The feed enters the top. In the low nitrate ion concentration, the uranium prefers the aqueous phase, and it leaves the organic as the two solutions counter flow. It exits the bottom of the stripper in the form of uranium nitrate. The organic hexone exits the top of the column and is then sent to K cell for recovery and re-use. The uranium nitrate from the stripping column is quite dilute. It is concentrated in a continuous evaporator and then sent through second and third cycles of extraction in Q and S cells. The second and third cycles are very similar to the first. The final product is concentrated and sent to the product storage cell where it is bottled for shipment.

Through the three cycles of extraction, the decontamination is nearly perfect. However, traces of ruthenium occasionally follow through with the uranium, and when this happens, it must be recycled for the extraction of this troublesome element.

The capacity of the batch process depends on the head end or dissolution rate. There are four dissolvers in the system, but the capacity is still low.

2. The Continuous Dissolver Process

To correct the bottle-neck in dissolution, a continuous dissolver system was constructed in G cell. It consists of a long column into the top of which the fuel elements are fed by way of a charging chute from the Process Makeup Area floor. Nitric acid and catalyst are pumped into the dissolver at the bottom. As the elements dissolve they drop to the bottom of the column and fresh elements are added at the top. Coming out near the top of the dissolvers is a continuous stream of dissolved material. Gases generated by the dissolving process are bled off through a reflux condenser where vaporous nitric acid is condensed and salvaged.

From the dissolver the solution passes through a filter and into a run tank. The solution is quite dilute and so it is concentrated in a continuous evaporator. Figure 45 is a flow diagram of the process.

The first cycle of extraction takes place in columns in G and H cells. These columns differ, however, from those in P, Q, and S cells in that they are pulser type columns instead of the packed type. The capacity is greater and the length required is much less. In order to get intimate contact between the organic and aqueous solutions, the liquid inside the column is pulsed, forcing it through perforated baffle plates. This breaks the two liquids into small drops which can flow counter current due to their different densities.

TBP, the organic solvent, is introduced into the column near the bottom and the aqueous feed at the top somewhat similarly to the

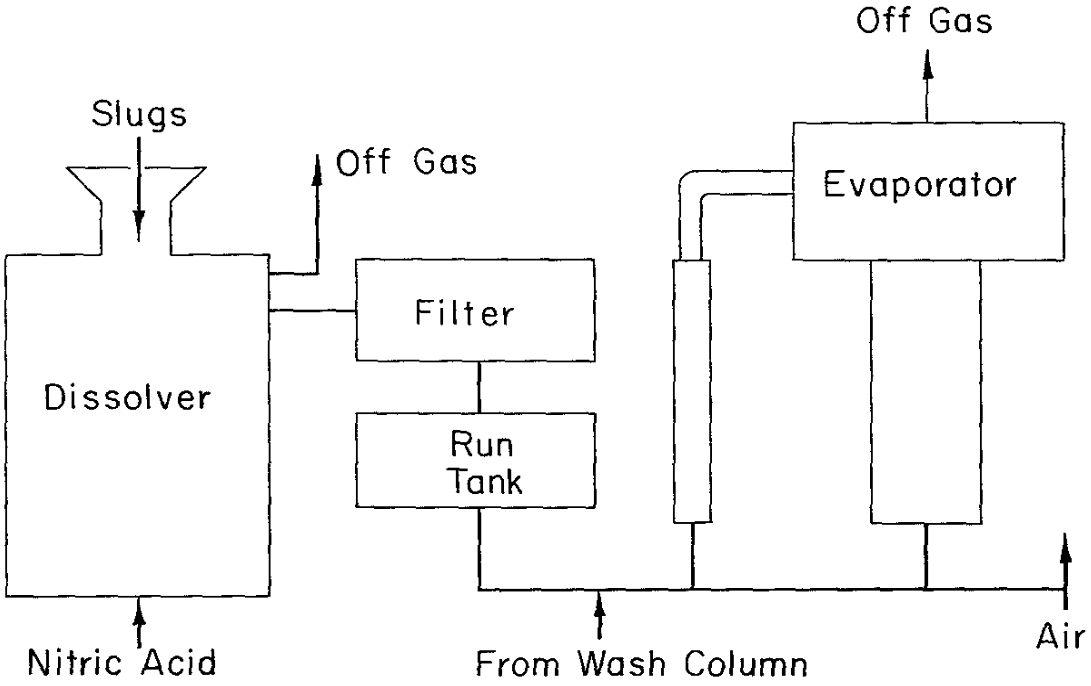

Figure 45

ICPP Continuous Dissolver Process Flow Diagram

way it is done in P cell. Again because of the difference in solubility of the uranium under the influence of nitrates, the organic extracts it from the aqueous leaving the aluminum and fission products behind. The organic is next washed with aluminum nitrate to remove any trace of fission products which may have been entrained in the stream and then sent on to the stripping column where the uranium is back-extracted into the aqueous phase by washing it with dilute nitric acid. The organic is now depleted of uranium and is refined and re-used. The aqueous stream is washed with kerosene (amsco) to remove the last traces of TBP and concentrated for further refinement in the second and third cycles in P and Q cells. Figure 46 shows the flow diagram for the extraction part of the continuous system.

The continuous dissolver system has a very high capacity. It is used for nearly all of the aluminum fuels and has been a very successful part of the plant.

3. The Zirconium Process

Processing zirconium differs little from processing aluminum. However, zirconium will not dissolve in nitric acid, and so a mixture of nitric and hydrofluoric acid is used to dissolve the elements. The dissolver is made of monel, an alloy which resists the action of both nitric and hydrofluoric acids. One cycle of extraction in F cell separates the fluorides from the product stream and prevents them from corroding the stainless steel piping and equipment. The

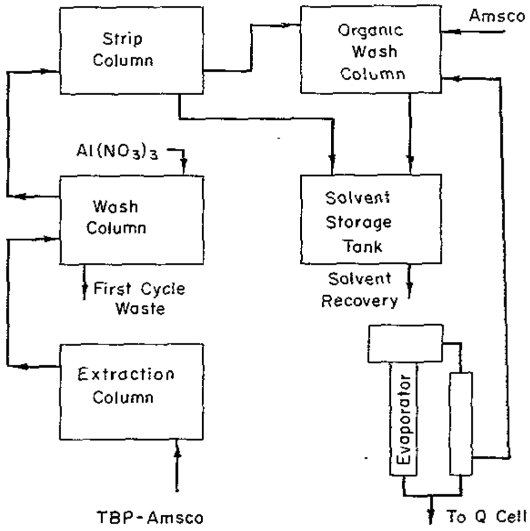

Figure 46

ICPP Continuous Dissolver Process
Extraction System Flow Diagram

fluoride waste is treated with aluminum nitrate and stored separately from the other plant waste. The uranium nitrate product can be sent on to the second and third cycle in P and Q cells.

The zirconium dissolver incorporates a soluble poison to reduce the danger of a nuclear chain reacton when large amounts of uranium are in it. Boric acid is added to the dissolver before the uranium is charged. The boron in the boric acid absorbs neutrons and prevents them from causing fission. The poison significantly increases the capacity of the system.

In order to insure the proper boron content, a neutron source is placed along the side of the dissolver. A neutron detector measures the absorption of the thermal neutrons through the solution. If the boron is too low, the neutron flux is high and gives warning so that additional boric acid can be added before trouble develops.

4. Stainless Steel

Dissolving stainless steel fuel is a problem. Sulfuric acid will dissolve stainless steel but will not dissolve uranium. Nitric acid will dissolve uranium but not stainless steel. A mixture cannot be used because if the stainless is contacted with nitric acid, sulfuric acid will not dissolve it. The dissolution is therefore carried out in two steps. The stainless steel is first dissolved in sulfuric acid, and the residual solids which are primarily uranium are then dissolved in nitric acid. Before the next batch is charged to the dissolver, every trace of the nitric acid must be removed, and a small ball of steel wool must be placed in contact with each fuel element as a catalyst to trigger the sulfuric acid reaction in the next batch.

One cycle of extraction removes the sulfate and forms uranium nitrate for further extraction in the second and third cycles in P and Q cells. Sulfate waste must be treated separately and stored in special waste tanks just as with zirconium fluoride waste.

Both the zirconium and stainless steel sections of the plant are located in cells E and F. The recovery of uranium from these types of fuels is very costly and slow. However, the addition of soluble poisons for the zirconium process and the development of a new electrolytic stainless steel dissolver will make them more economical.

5. The RaLa Process

Most of the plant is concerned with the recovery of uranium from spent fuel and fission products. The RaLa process was concerned with the recovery of a fission product. RaLa stands for radioactive lanthanum, a fission product valued for its high energy gamma radiation.

In RaLa, a fresh fuel element just out of the MTR was dissolved in caustic, and Ba-140 extracted from it by a series of precipitations and redissolutions. Barium-140 decays to La-140 which then could be separated and used.

6. Remote Sampling

As in any chemical plant, sample analyses form the basis for control of the process. Radioactivity of the solutions sampled at the ICPP complicate the sampling procedure. All samples of process solutions must be removed from the process without exposing personnel to the associated radiation. Fission products in the sample solution make contamination of the sampling equipment and sampling area a problem during plant operation. Designers of the remote sampler and the sample transfer shield, or sample pig as it is called, considered these problems and tried to minimize them as much as possible.

The remote sampler draws the sample from the process stream inside of the cell and discharges it into a small glass bottle. A sample line and a sample return line penetrate the cell wall connecting the sampler with the vessel to be sampled. In some places a small vessel, called a sample pot, is used specifically for sampling. In many others, the sample is taken directly from the vessel. An air jet provides the force required to move the sample stream through the sampling lines.

In Figure 47 the various parts of the remote sampler are shown. The sample and jet are located inside a 4 in. lead and steel shield. A 4 in. lead glass window penetrates this shield at each sample station so that the operator can observe the sampling operation. A sample blister may contain one or more sample stations. Each sample blister is equipped with a remote handling device, a light, and a shielded area where the sample can be transferred into a transport shield. This area is called a sample pig garage, and the transport shield, a sample pig.

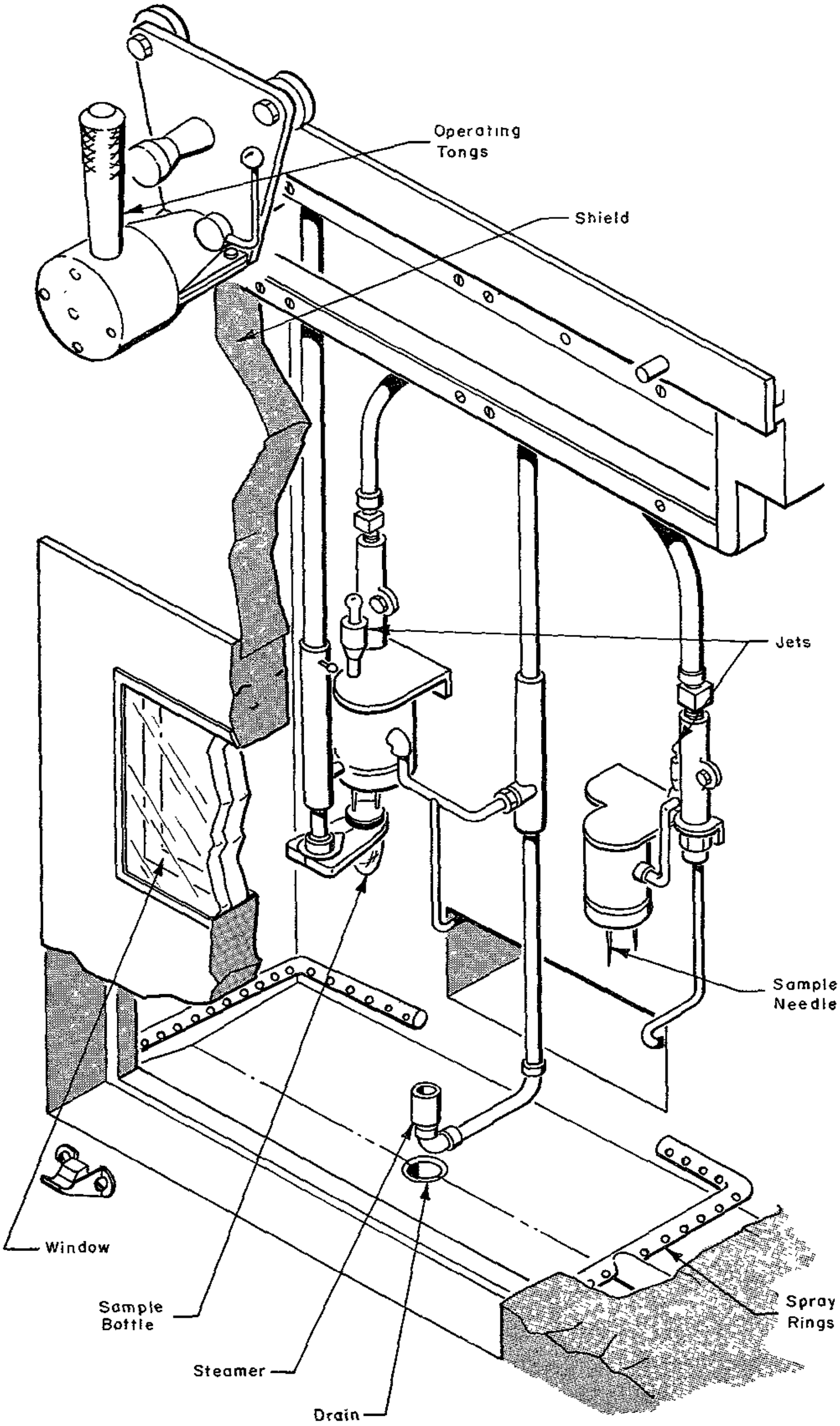

Figure 47

ICPP Remote Sampler

The sample handling device (sampler tongs) penetrates the shield at the top edge through a slot running lengthwise of the sample blister, the bottle clamp being inside of the shield and the operating controls on the outside. The sampler tongs are suspended from a rail running parallel to the slot. These rails both support and guide the sampler tongs as the sample is moved from the station past other stations to the pig garage.

The entire blister is ventilated by a separate system that draws air through the various openings through a filter and exhausts it to the stack by way of the vent tunnel. Rubber flaps close most of the sample tong slot, limiting the air flow to a reasonable amount.

Washdown systems and drains are provided so that a reasonable cleanliness can be maintained inside the sample blister. A sample line steaming device is also provided for the sample needle so that the sample line can be cleaned and occasional plugs removed.

Sample containers consist of either tear drop shaped 7-1/2 ml or cylindrical 25 ml glass bottles. A special cap is used which permits the penetration of a rubber gasket by the two hollow sample needles. The sample is drawn from the sample pot or vessel through the sample line and is injected through a hollow needle into the sample bottle. A shorter needle produces a vacuum on the bottle and draws off surplus sample. The vacuum is provided by the air jet which discharges through the sample return line back to the sampling point. By this means, a circulation is set up so that a representative sample can be obtained. When the air to the jet is turned off, a small amount of sample remains in the bottle. This sample volume is controlled by the length of the sample needles. After the bottle has been removed, the steamer is placed over the sample needles; and the needles, lines, and jet are cleaned with steam so that the next sample taken at the station will not be adulterated by residue from the last sample. This steaming operation also maintains clear lines and prevents line plugging.

After the sample has been drawn into the bottle, it is transferred to the sample pig in the sample garage. The sample pig has about 5 in. of lead shielding and weighs approximately 550 pounds. A drawing of the sample pig is shown in Figure 48. Each pig has space for at least two sample bottles. Many have space for three. A small hand-operated plunger lowers the sample into a turntable inside the pit. The turntable can then be shifted so that the sample is no longer aligned with the entrance plug held in place by gravity.

The sample pig is carried from the sample station to the Remote Analytical Facilities (RAF) by a sample transport cart. The height of the platform holding the sample pig can be raised or lowered to match the levels of the various sample garages. When moving the pig off or onto the cart, two small dogs engage a bar and lock the cart to the garage so that they cannot separate and drop the pig in between. Once on the cart, the pig is prevented from rolling off by a simple latch attached to the handle of the pig. The cart and pig can then be moved without danger of damage to the pig by its accidently rolling off onto the floor.

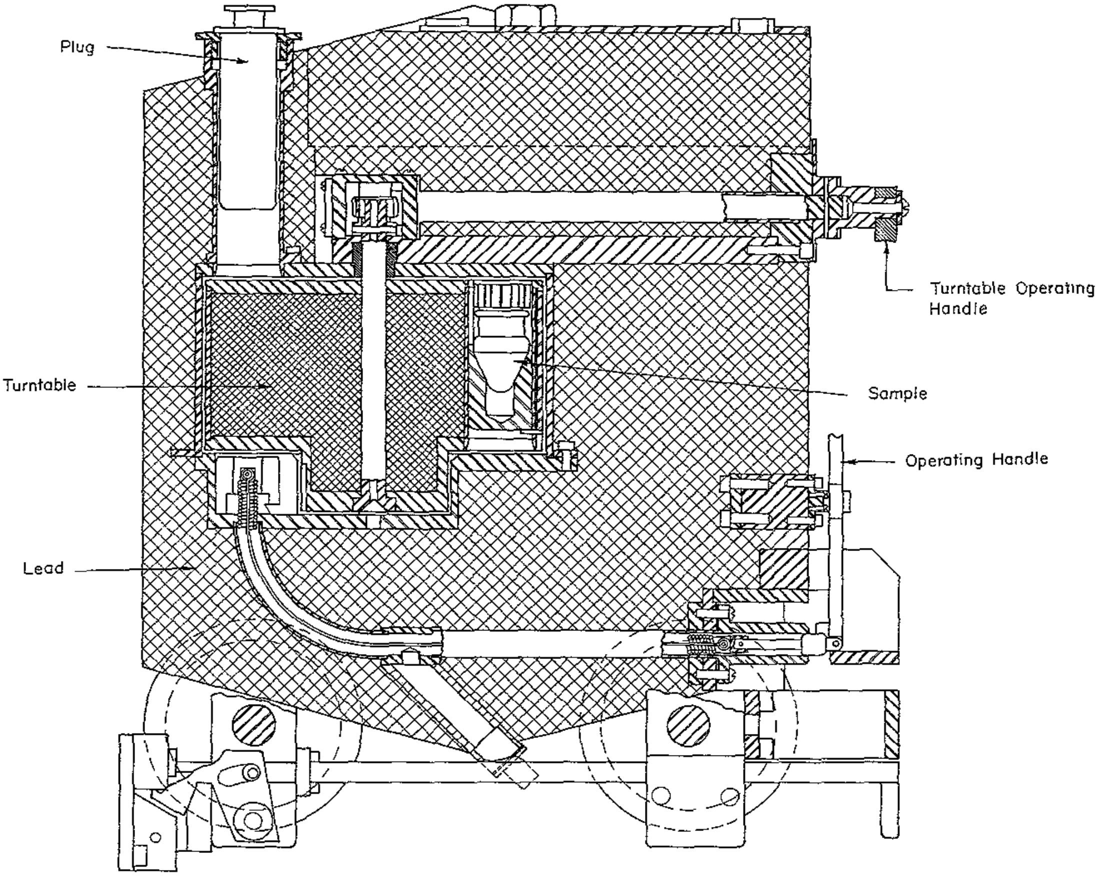

Figure 48

ICPP Remote Sampler Sample Pig

Due to the remote handling equipment and the adequate shielding, the radiation hazards connected with the sampling procedure are not very great. Contamination hazards are significant, however, due to the fission products contained in the sample solution. Samples may contain many curies of mixed fission products. A small droplet of this solution, if allowed to spread, can contaminate the entire operating area to a sufficiently high level as to require a thorough mopping.

As the sample bottle is being removed from the samplers, a drop or two may drip from the hollow needle, falling on top of the bottle or running down the side. These can then contaminate the sample tongs and the sample pig. Since the samples are generally an aqueous acid solution of a salt, evaporation causes a residual solid to be left behind on the surface. This solid is of such a nature that it bonds only slightly with various surfaces and can be easily dislodged, either falling on the floor or carried by air currents. The residue is quite soft and easily crushed into fine powder which may adhere to the soles of shoes. A portion of this material may be left on the floor with each step. The solids may be only a microgram in weight but may contain many micro-curies of radioactivity.

Probably the greatest source of contamination and the most troublesome is the sample pig itself. The operator must handle parts of the pig in the routine of sampling. A small amount of radioactivity on the pig is thereby transferred to the operator's hands, and the sampler operating handles then become contaminated. Care is required on the part of the operator at all times to prevent this type of contamination transfer.

A circular piece of blotting paper is used to cover the entire top of the sample pig. The solution is absorbed by the paper, and the solids left upon drying tend to be trapped within its fibers. A radiation survey discloses the contamination, permitting it to be discarded before it becomes either a radiation or a contamination hazard.

The interior of the sample blister, including the garage, becomes highly contaminated by the day-to-day sampling operation. It can be washed down somewhat by the built-in spray system. However, broken sample bottles and lint from inside the sampler may clog the drain. If the drain becomes clogged or the washdown spray is turned on too vigorously, the surplus water containing fission products can run out onto the floor penetrating not only the cracks between the floor tile but also the pores of the tiles themselves, resulting in the creation of contamination sources not easily removed. Whenever a sample blister is accidently overflowed, it is generally necessary to replace a number of the floor tiles before the area can be kept clean.

Occasionally, a faulty or strained sample bottle is encountered. Extremely high level samples cause added weakening of the glass through radiation damage. These bottles are quite easily broken, discharging their contents in many different directions. A broken sample bottle inside the sample pig may jam the mechanism preventing the removal of the glass and the contamination. The pig must then be disassembled and repaired. To minimize the frequency of this breakage, each bottle is closely examined. Any questionable bottle is dropped several times on the floor. A good bottle will not break. A faulty one will crack or shatter. In any case, the bottle is again closely examined and discarded if any flaw or crack appears. The operator must make sure the sample bottle is properly seated in the turntable inside the pig before it is rotated. Otherwise the bottle may be crushed.

Sampling at the ICPP requires that careful procedures be used at all times by operating personnel if widespread contamination is to be prevented. The presence of constant radiation monitors in the sample corridors and on-the-job surveillance of each operation by a competent health physicist with a monitoring instrument will supplement but not replace the caution and skill of the operator.

7. CPP Shielding Compromises

The dissolution of a reactor fuel element at the CPP will result in very little reduction in its radiation intensity, and the reduction of radiation hazards is not of much consequence as the resulting solutions are distributed along the subsequent piping and vessels. Each of the cells, therefore, is constructed with five foot thick concrete walls. They are lined with stainless steel for easy decontamination.

The penetrations of the walls contain bends, thereby preventing leakage of radiation from the inside of the cell to the outside. They are made for instrument leads of various kinds and for the working hydraulic fluid of the remote pulse pumps, which supply the impulses for driving solutions through the extraction columns. Shielding cannot be compromised here by direct radiation through the holes. Sometimes radioactive fluids from the process get into exposed instrument leads and parts of the pulse pump systems which normally would be clean. The introduction of these highly radioactive fluids into lines in the Operating Corridor and the Access Corridor give rise to troublesome high radiation fields.

At the end of a production run, it is usually necessary to perform maintenance work on the process piping, vessels, and instrumentation within the cells. Before anyone attempts to enter the cells, it is necessary to decontaminate the piping and vessels internally. This is done by remote control and ideally would result in reduction of radiation to quite low work levels. This does not always happen, however. If there has been any leakage of radioactive solutions from any part of the process system, the cell walls, the floor and external areas of the piping and vessels may be highly contaminated. A spray system is built into each cell to wash down the process system exteriors and cell surfaces. This reduces the radiation to a level which permits removal of the top hatch and subsequent surveys by Health Physics. If further decontamination of exterior surfaces is required, it may be attempted with a hose, directing water and other decontamination media at the hot spots.

Hot spots may persist, however, either inside or outside of the process system. It is, therefore, often necessary to provide temporary shielding to allow work to be done in the cells. Even so, the allowable work time may be very short, and the health physicist must maintain tight control over this aspect of the work.

C. CPP Chemical Laboratories

1. The Shift Control Laboratory

The sample pigs mentioned above are transported to the Remote Analytical Facility (RAF) where the hot samples are transferred to shielded caves which are equipped so that the samples may be diluted. The diluted samples, again in bottles, are transferred into a dumbwaiter and elevated to the east hood in the Shift Control Lab on the floor above. There is a small facility within the hood for shielding the hot samples. The samples are then further diluted by a factor which may vary from 10 to 100. All of the work just described is done with Safe Work Permit Procedures and requires continuous HP surveillance.

The dilutions are marked according to the radiation fields surrounding them and then removed to open benches for the necessary analysis work. Note that each step of this procedure has consisted of a controlled breach of the previously effective radioactivity containment. At each succeeding step the potential degree of contamination is lower and the successive containment measures are less stringent.

2. X-Cell

As mentioned previously, the shielded process cells in the CPP are designated by letters of the alphabet for identification purposes. Some other areas within the main plant building, associated with the plant but not necessarily process cells, are also called cells and given a designating letter. X-cell is among this latter group.

Originally X-cell was the high level radio-analytical control laboratory. High level radioactive samples from the process were analyzed there for plant control data. An improved version known as the Remote Analytical Facilities (RAF), now functions in this capacity. Since it was no longer needed, X-cell was remodeled and converted into a research laboratory equipped to handle high level alpha emitters. Even though it was extensively decontaminated, some isolated residual radiation may still be detectable from contamination incurred during the original use of the cell.

The equipment now in X-cell consists of a 4 in. lead equivalent shielded cave with two master slave manipulators and four glove boxes in series with the shielded cave. One hood, a sink, and laboratory bench space are also included. The cave and glove boxes have individual absolute filters and are exhausted to a common duct, filtered again with an absolute filter, and then exhausted through the roof of the CPP 601 building. The hood has a separate duct, absolute filter, and exhausts through the roof. All drains from the lab go to the Process Equipment Waste (PEW) and are considered hot drains. Ventilation is provided by air flowing in through an opening over the entrance door and being exhausted out through the glove boxes, cave, and hood.

The permanently installed HP monitoring instruments in X-cell consist of: (a) a 1 in. sampling tube connected to a CAM (NMC AM 22R) in adjacent V-cell, which is capable of detecting alpha and beta-gamma airborne radioactivity, and (b) an ORNL monitron which is capable of detecting high levels of gamma radiation. Both instruments alarm in the HP field office (V-cell) and the laboratory (X-cell). There are also low flow alarms on the four glove boxes.

Portable HP monitoring instruments kept in the cell include a GM survey meter, a Juno, and a gas proportional alpha survey meter. These are maintained for the convenience of the laboratory personnel and the HP technician responsible for the area.

The main hazards of the laboratory operation are connected directly with the nature of the materials handled and the work being done in the cell. Gram quantities of alpha emitters such as neptunium, plutonium, americium and other transuranic elements have been successfully processed in this laboratory. Pure fission product radioisotopes of strontium, ruthenium, and zirconium have also been used. These radioactive materials are handled in the hood, cave, and/or glove boxes, depending on the amounts, concentrations, and chemical composition.

One health physics technician is assigned the responsibility for the radiation safety in the laboratory. He makes a routine daily smear and radiation survey of the cell during any time that significant quantities of radioisotopes are handled. He sees that the isotopes are properly handled in the appropriate equipment. He provides constant monitoring during any particularly hazardous work, such as sample transferring, or any time the lab personnel request it.

Monthly 24-hour urine samples are collected from all personnel who frequent X-cell, including the HP technician. These samples are routinely processed for gross alpha, beta, gamma, and plutonium. Any radioactivity detected by gross analysis is identified, and additional samples are requested when it is thought to be necessary.

Clothing used by the lab personnel is surveyed separately. If there is detectable alpha contamination, the clothing is considered plutonium contaminated and kept separate from the rest of the CPP laundry. It is given special handling both at the CPP and the CFA laundry.

X-cell has not caused any major contamination problems outside of the lab itself. This can be attributed mainly to the extreme caution and conscientious action on the part of the highly skilled research chemists. Willing and free cooperation between the lab personnel and the attending HP technician is maintained on a high level. This cooperation must be maintained in order that the work done in the X-cell laboratory is carried out safely.

D. Waste Treatment

The liquid waste at the ICPP consists of three levels: (1) high level solution from the extraction column, (2) intermediate level waste solution from the plant process, and (3) low level liquid material from the plant.

The high level waste is the by-product of the extraction process. The intermediate level wastes are cooling water, steam condensate, and other relatively non-contaminated waste waters. The high level liquid waste is treated only slightly before being permanently stored. The first cycle waste, containing fission products in amounts from 10 to 100 curies per liter after being concentrated, is transferred to the 300,000 gallon stainless steel tanks buried in the ground. There the waste solution, in an acid condition, is stored indefinitely. With fresh, high level waste, thermal cooling must be provided to retard corrosion. Cooling coils have been installed in several of these tanks, and the solution is cooled periodically for several years until radioactive decay permits storage without cooling. The second and third cycle waste is re-used in the plant.

The intermediate waste generated by equipment wash and decontamination is first collected at the south end of the plant. There it is sampled to make certain that it does not contain uranium. If some uranium is present, it is sent to J cell for recycling through the plant extraction system. If it does not contain uranium, it is sent to CPP 604 so that most of the water can be removed in a special evaporator. The radioactivity in the condensate from the evaporator is measured, and it is discarded to the low level waste system. The bottoms left in the evaporator are then transferred to the permanent storage.

The low level (Service Waste) material is discharged to the water table by way of a 600 foot disposal well. While being discharged, the water is monitored and sampled. Only very dilute radioactive waste is permitted to be discharged to the water table.

Gaseous waste products are discharged to the atmosphere by way of a 250 foot concrete stack. These gases come from the dissolver off gas (DOG), from the vessel off gas (VOG), and from the cell, sampler, and plant ventilation systems. The DOG contains Kr-85 and aerosols of most fission products. The VOG contains aerosols of fission products, and the cell and sampler off gas contain other radioactive particulates generated in the plant. The ventilation system, the major bulk of the stack discharge, contains dust and dirt but very little radioactive material except that from the cell and sampler ventilation. A monitoring and sampling system provides an alarm if unusually high levels of radioactive material are being discharged and enables health physics to measure the radioactivity for reporting purposes.

E. The Calciner

Waste disposal is one of the greatest problems connected with all reprocessing of reactor fuels. The storage of waste is expensive, and a reduction in bulk is very desirable. One such method is to solidify the liquid waste in a calciner. A reduction in bulk by a factor of 8 to 1 can be obtained by removing only the nitrate and the water in the waste solution. This makes it a solid material more suitable for storage. A calcining system has been added to the ICPP waste treatment process.

The basic calcining process is as follows. Liquid is first evaporated by heat. By the application of air and more heat, the material is oxidized. Water and nitric oxide are given off. The resulting solid product is then stored in underground vaults. These solids contain nearly all of the fission products dissolved in the original waste solution.

The calciner at the ICPP is a fluidized bed type. A fluidized bed is formed when a quantity of solid, finely divided particles are made to exhibit many of the properties of fluids by injecting air into them from underneath. This gives the particles motion and makes the bed free flowing. Waste material to be calcined is sprayed into the bed. The heat supplied causes the water to evaporate, building up solid material on the particles already in the bed. As these particles become larger, the bed builds up and overflows into the transport system and is carried to the storage vault. Air from the transport system is returned to make up part of the fluidizing air sent through the calciner vessel and off-gas cleanup system. The flow pattern of material is shown in Figure 49.

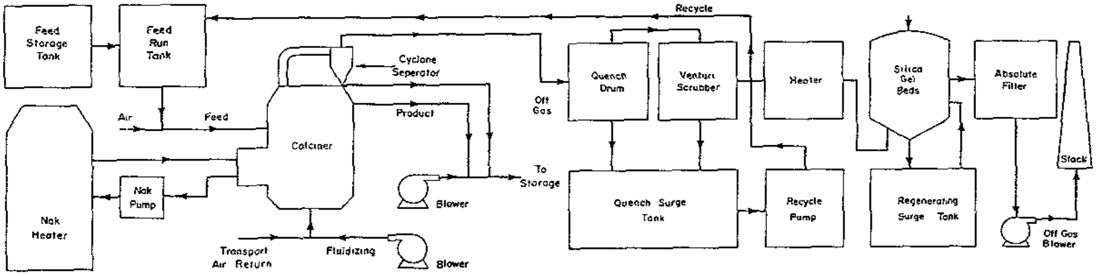

Figure 49

ICPP Calciner Flow Diagram

Heat is supplied to the calciner by a liquid metal or NaK* heat exchanger system. NaK is heated in an oil-fired furnace, pumped through the calciner where it gives up its heat, and then it is returned to the furnace again. Over five hundred gallons of NaK are used in the calciner heating system.

Figure 50 is a drawing of the calciner vessel. On the left side is the heat exchange base. On the far left is the NaK inlet. The NaK travels down the center of a bayonet tube and returns near the outside into the center section labeled the NaK outlet. On the right of the heat exchanger section is the monitoring helium manifold. Helium under pressure surrounds the bayonet. An alarm is given if either the NaK tube or the outside protector tube is ruptured and causes a change in helium pressure. In the upper left hand corner of the drawing is a detail of the feed nozzle. Air and liquid are injected simultaneously into the calciner vessel through this nozzle. The size of the droplets entering the calciner is controlled by adjusting the air pressure and the volume of liquid. The calciner operates at about 400 degrees centigrade.

Radioactivity must be removed from the off gas before the off gas can be discharged to the atmosphere. The first phase in the off gas cleanup is the calciner cyclone. A drawing of it appears in Figure 51. It is located on the top of the calcining vessel, and as the gas passes through the cyclone separator, the fine material is removed and fed back into the product take off line. The off gas, cleaned of large particles but still containing

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* NaK is an alloy of sodium and potassium. It is a liquid at room temperature, even though sodium and potassium are solid metals at this same temperature.

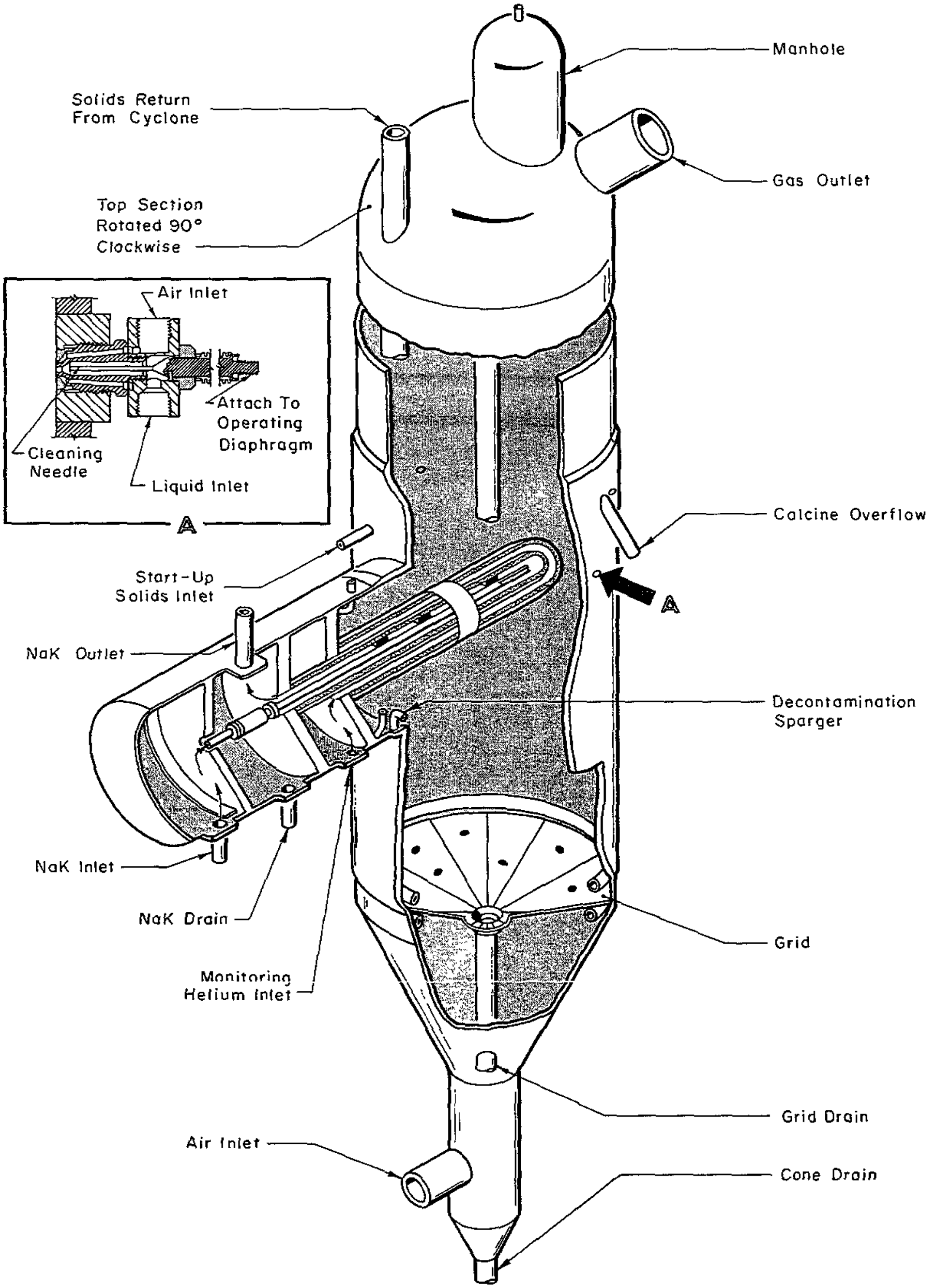

Figure 50

ICPP Calciner Vessel

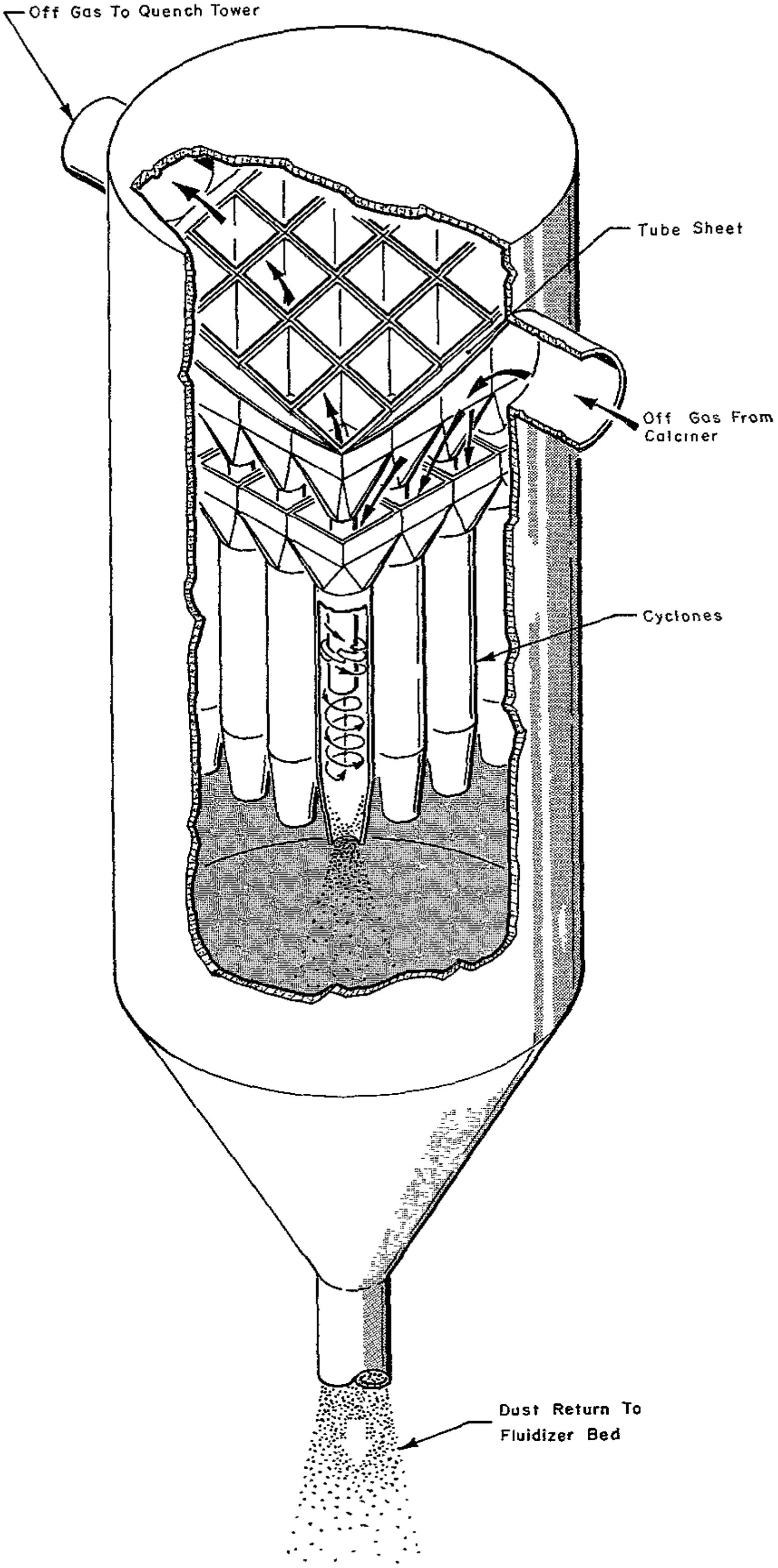

Figure 51

ICPP Calciner Cyclone

some fine particulates, is then transferred to the quenching drum where it is cooled. In the quenching drum a spray of water quenches the gas to a temperature of about 80°C. This also removes some dust and nitric oxide.

Further dust removal is accomplished in the venturi scrubber. (See Figure 52.) Gas, laden with dust, enters the venturi scrubber through the top. The venturi increases the gas velocity and causes the very fine dust to impinge on the water spray at the center of the venturi. The water is then separated from the gas by cyclone separation. The dust laden water is fed back to the quench surge tank. Part of the quench solution is recycled through the calciner to maintain a balance in the solids and water.

After leaving the venturi scrubber, the gas is reheated to decrease the relative humidity. It passes into silica gel absorption beds in which radioactive ruthenium is absorbed. From the silica gel beds the off gas passes through absolute filters to a blower and is discharged to the stack. The silica gel beds can be regenerated by removing the ruthenium with water. The water containing ruthenium is sent to the intermediate level liquid waste system and evaporated. It ends up in permanent storage where it may eventually be recycled through the calciner again. As the absolute filters become dust laden, they can be replaced remotely and shipped to the burial ground for disposal.

The off gas discharged to the stack still contains oxides of nitrogen, some small calcine dust full of fission products, and gaseous compounds of ruthenium that have not been absorbed on the silica gel beds. A strict monitoring system is necessary to prevent the dangerous discharge of materials through the stack.

Figure 53 shows a diagram of the original storage bins. Each bin has three concentric sections with air circulating between them for cooling. The arrangement of the calcine flow is such that one bin is filled at a time. As one bin fills, it overflows into the next until all are full. Cooling air can be circulated by blowers to prevent the calcine from heating to a greater temperature than that of the calcining process. Normally, natural convection provides sufficient air circulation for cooling. The original design has been modified for the more recently constructed bins.

F. CPP Auxiliary Facilities

Besides processing spent reactor fuels, the CPP is engaged in research and development work, trying constantly to improve reprocessing technology. Reactor development programs are continually developing new fuels that present special problems in reprocessing. The Process Improvement Facilities (PIF) and the Hot Pilot Plant (HPP) are providing information to overcome these problems.

The PIF consists of a laboratory building with office space for the technical group. New ideas in reprocessing are developed and investigated here on the laboratory bench. The laboratories

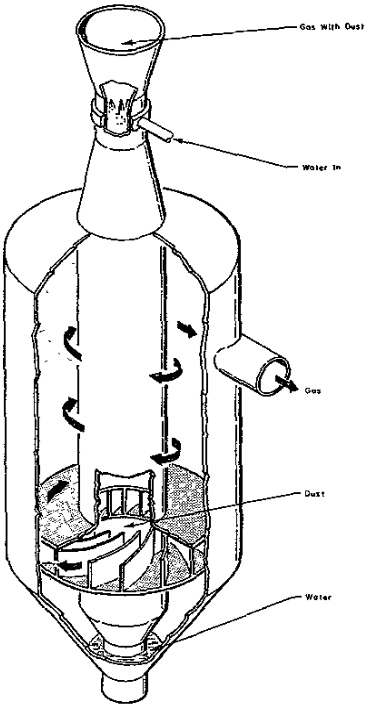

Figure 52

ICPP Calciner Venturi Scrubber

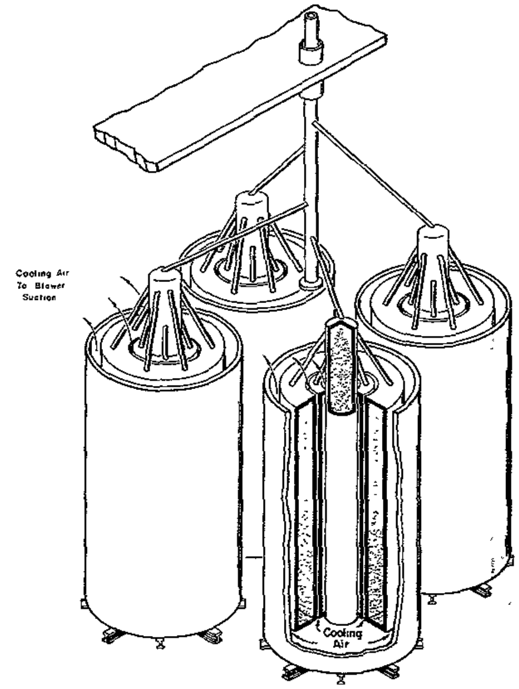

Figure 53

ICPP Calciner Original Storage Bins

were designed to handle up to 1 curie of radioactive material per laboratory with the waste stream being discharged into the Hot Pilot Plant waste system.

The ICPP Hot Pilot Plant is used to test unproved equipment and systems before large sums of money are spent to install them in the plant proper. A system can be investigated on a pilot plant scale with a great deal of versatility. The facility consists of three cells and associate utilities. The partition between two of these cells can be removed making one large cell. The shielding around the cells is equivalent to that of the main plant and will provide sufficient radiation shielding to run plant level radioactive material. Equipment can be installed and tested in these facilities and the process flow sheets worked out before any equipment is installed permanently in the main plant.

The waste system in the HPP consists of three-level storage similar to the plant proper. The high-level waste in storage can be routed to the permanent storage tank. The intermediate-level waste can be routed either to the waste evaporator system or the low level waste tanks. The low-level waste is monitored and discharged to the disposal well down stream from the main service waste monitoring system. A service waste monitoring system is provided for this secondary stream.

G. CPP Health Physics Problems

Contamination control is a major item of health physics consideration at the CPP. Not to be neglected, however, are the problems associated with fission product radiation and the handling of large amounts of highly enriched uranium. These three areas comprise most problems of which any CPP health physicist must be constantly aware.

1. Contamination

The radioisotopes with the CPP are aged fission products and have long average half-lives. At the time of processing, the first cycle waste stream has an average half-life of approximately one year. Any piece of equipment or area contaminated with these fission products must be either decontaminated or avoided entirely since the contaminant will not decay away in a reasonable length of time. Making each individual employee at the CPP responsible for decontaminating his own spills decreases the tendency for the employees to be careless and helps to control contamination. In some cases, however, this is not practical, and decontamination facilities operated by health physics provide an economical and reasonable way for cleaning such things as tools and plant equipment.

Additional contamination control is provided by area designation. The main part of the CPP is declared a "hot area" in which protective clothing is worn at all times. This consists of plant-provided shoes and lab coats or coveralls. Unprotected street clothing is not permitted in a hot area. On the second floor of CPP Building 602 where offices, the cafeteria, and dispensary are located, the reverse is true. This is declared a "cold area" in which street clothing or uncontaminated coveralls protected by the cold area lab coat are permitted. No plant shoes are permitted in this area. Within the CPP the only area in which both street clothing and protective clothing are permitted simultaneously is in the locker room change area.

The exits in the plant area are monitored by portal monitors in certain strategic locations so that no significant radioactive contamination can be inadvertently carried from the plant on clothing or equipment. A rigorous program of smear surveys indicates low level contamination so that it can be removed before a contamination problem can develop. Actual area contamination is relatively rare throughout the plant. However, the potential is significant and prompt action is required any time contamination is found.

A chronic problem at the CPP is the solvent burner. Waste solvent from the continuous process cannot be reclaimed and must be disposed of by incineration. The combustion products are discharged to the stack. The first solvent burner has burned out and has not been repaired. Present plans are to convert the unused stack heating furnace to solvent incineration.

2. Special Problems in the Operating Corridor

Within the CPP the backup of radioactive material from the cell into the operating area process lines constitutes a special problem. The entire plant is operated remotely. Steam lines leading from the operating corridor into the cells provide systems for transferring solutions from one vessel to another. If these steam lines are not properly vented after an operator makes a transfer, steam condensing will cause a vacuum, drawing the radioactive material up into the steam supply line. At times, very high radiation fields can exist in the operating corridor. Area monitoring systems have been installed that indicate by alarm each time such a condition exists, and immediate corrective actions can be taken. Residual contamination usually remains after such an occurrence. In some cases it has been necessary to remove these lines and replace them. However, most residual contamination can be driven back into the cell by the application of more steam through the line.

With so many valves, addition funnels, and other openings into the operating area at the CPP, it is possible to get airborne radioactive contamination into the building by someone inadvertently permitting one of these valves to remain open. Constant air monitors are provided in all areas to detect airborne radioactivity. Whenever a CAM alarms, the source of the airborne radioactivity must be discovered and corrected to prevent future recurrences.

All area monitoring equipment information is transmitted to a central alarm board in the health physics field office. Each time an alarm occurs on this board, the technician on duty must investigate quickly and locate the source of the trouble. Otherwise a minor problem may become a major source of contamination.

3. Criticality

The CPP was designed to process fully enriched uranium fuels. In order to do this safely, accidental nuclear fission chain reactions had to be engineered out of the plant equipment as much as possible. Criticality was considered anywhere that uranium could possibly accumulate. Vessels which normally contain uranium were constructed in shapes and sizes such that nuclear chain reactions would be impossible. In other places the nuclear fission poison, boron, was incorporated into the equipment or added to solutions to absorb neutrons and prevent criticality. Concentrations and quantities of uranium are controlled in some cell equipment where this is the most practical means of solving the problem.

In some areas in the plant the design could not entirely eliminate the criticality problem. In these areas strict administrative procedures are depended upon to keep the operation safe. In C and D cells a time lock is placed on the charging chute cover so that the time necessary to accomplish complete dissolution of the fuel must elapse before additional fuel can be added. However, in charging the continuous dissolvers in G cell, the amount of fuel permitted in the charging cave at any one time must be controlled by the operators so that this system cannot go critical. All water lines and decontamination lines that lead into the cave are locked and sealed so that water cannot be introduced into them to moderate the fuel and thereby decrease the amount of uranium necessary for criticality.

In the product bottling room, the number of product bottles is controlled. One bottle may be filling while another is being weighed and sampled, but no more than this number of bottles are permitted in the room at any one time. As soon as a bottle has been filled, weighed, and sampled, it is placed in a shipping container called a bird cage and removed to the storage vault. A partition has been built in the center part of the storage vault to separate the shipping containers so that only one line of filled bird cages can be stacked against each wall.

So long as the administrative controls are not violated and procedures are properly followed, the routine operation of the plant is quite safe. However, whenever the routine is broken by something such as a plugged process line, the possibility of criticality increases. Any operation which is not a standard operating procedure must be viewed by HPs with suspicion. Each step must be carefully reviewed with criticality safety in mind. Only experienced, qualified personnel are allowed to handle significant quantities of uranium on a nonroutine basis.

A committee of experts known as the Engineering Safeguards Committee is responsible for reviewing any and all changes in plant equipment and/or operating procedures for nuclear criticality safety. Only by continual improvement and constant review of all factors involved can the CPP be kept safe from an accidental criticality.

4. CPP Storage Basin

A health physicist should monitor all items removed from the CPP basin. It is the responsibility of personnel working in this area to call for health physics coverage as needed.

5. Processing Areas (i.e., cells, tunnels, RAF lines, fan rooms, etc.)

There are many such areas at the CPP which may be considered in a group. Radiation levels in these areas, during plant operation, may be anywhere from several R/hr to several thousand R/hr. They are kept locked while the plant is in operation and are posted with large metal signs which say "Entry with HP Approval Only - High Radiation and Contamination Levels." When entry is required, special clothing and respiratory protective equipment are worn. For prolonged work, these areas are thoroughly decontaminated.

6. G Cell Cave

Any time fuel is dropped from a charger into the cave or from the cave into the dissolvers, an HP with a high range instrument will standby and monitor.

H. Summary

The CPP processes highly radioactive, fully-enriched, spent reactor fuel elements for the recovery of unfissioned uranium. By dissolving the fuel in various acids and separating the uranium from the waste material with a liquid-liquid solvent extraction system, nearly all of the unused uranium can be removed. Processing parameters are measured by remotely sampling the process streams and analyzing the samples for the information required.

The highly radioactive wastes generated are stored for an indefinite period of time. The liquid waste from the plant is reduced to a dry solid state by driving off the water and nitrates in a fluidized bed calciner. The dry form of waste has less bulk and is more suitable for long term storage.

Radiation safety is achieved by both plant procedure and design. Area designation and routine surveys control contamination. Criticality safety has been designed into the plant process and equipment, and administrative control assures that the safe design is not negated by improper procedure.

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CHAPTER VI

CENTRAL FACILITIES AND ASSOCIATED AREAS

A. Central Facilities Area (See Figure 54)

The Central Facilities Area (CFA) is a converted Naval Base which was used during World War II as a site for testing guns reconditioned at the Naval Ordinance Plant in Pocatello, Idaho. The old housing units have been converted into offices and are now used by the Atomic Energy Commission (AEC) and various AEC contractors.

The few buildings and areas in the CFA with any radiation hazardous materials in them will be discussed in this chapter. Other areas not directly in the CFA will be described only because CFA Health and Safety personnel are required to work in these areas.

1. CFA Buildings 610 and 616 (Idaho Nuclear Corporation Health and Safety)

a. CF 610

This building houses the Idaho Nuclear Corporation's Health and Safety Branch Manager, Industrial Safety Director, their staffs, and the CFA Health Physics Group. The radiation exposure records for all Idaho Nuclear Corporation employees and visitors are maintained in this office. Any employee or visitor may learn his exposure record by contacting the Exposure Records Section here.

The CFA Health Physics Group, under the supervision of the CPP Health Physics Supervisor, is responsible for radiation safety in the CFA and certain associated areas to be discussed later.

b. CF 616

This building is the headquarters for the Idaho Nuclear Health and Safety Branch Industrial Hygienist, CF Safety Engineer, and the Fire Protection Inspection Group. The services of the industrial hygienist are those dealing with toxicity, heating, ventilation, lighting, noise, sanitation, and lasers. He reviews all new and modification construction projects for possible health problems in these categories and spends considerable time conducting training sessions on industrial health in general.

The CF Safety Engineer's duties include all safety problems that are not due to radiation or do not fall within the responsibilities of the Industrial Hygienist in the Central Facilities or associated areas.

A major activity conducted from CF 616 is the inspection and servicing of fire and safety equipment. This program is under the direction of the Idaho Nuclear Corporation's Assistant Industrial Safety Director. Fire protection and safety equipment inspected includes: portable fire extinguishers, fixed pipe carbon dioxide systems, fire doors, built-in dry pipe extinguishing systems, automatic sprinkler systems, heat, smoke, and ionizing-type fire

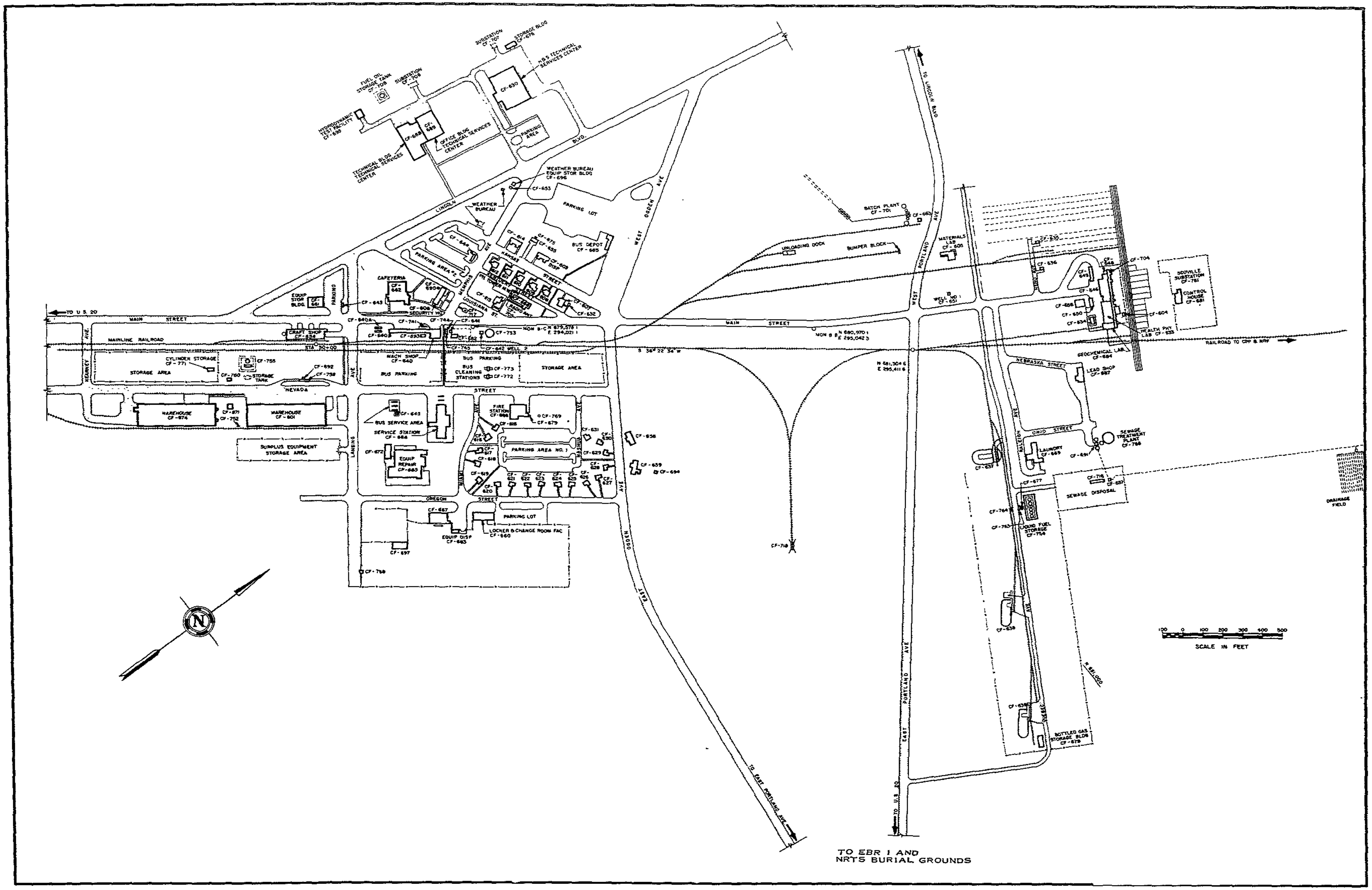

Figure 54

Plot Plan of
Central Facilities Area

detectors, fire hydrants, fire main valves, hose house equipment, inside hose systems, foam systems, ladders, emergency lights and stanchion kits.

Respiratory equipment in the plant areas is inspected periodically; however, this only complements the monthly inspections made by health physicists. An air compressor and a number of 230 cubic feet air cylinders are available for recharging the self-contained breathing units located at the plants.

In addition, equipment is available to the fire and safety equipment inspectors for in-line testing of high efficiency filters. Newly received filters are visually inspected at the CF warehouse.

The previously mentioned inspections are conducted for Idaho Nuclear Corporation areas. In addition, the fire protection equipment inspection service is conducted for the AEC and Phillips Petroleum Company.

2. CF 669 (Laundry)

The Central Facilities Laundry is maintained for convenience in handling contaminated clothing or protective clothing which has been used in radioactive areas. Laundry services include washing, drying, pressing, folding, and repairing of protective clothing. Because of the risk of possible contamination, no other items should be washed at this laundry. Any non-contaminated clothing is sent to commercial laundries.

Clothing being sent to the CFA laundry is segregated as to type (shoe covers, coveralls, gloves, etc.) and radiation level. After it has been laundered and dried, the clothing is monitored on special tables. Each general type of clothing has its own permissible radiation limits. Any item which exceeds the recommended permissible limits is rewashed. After a 30 to 90 day decay period, Anti-C clothing that cannot be decontaminated and is not below these levels is bagged, labeled, and returned to the plant for disposal or use as determined by the plant Health Physics section.

The foreman's office is designated as a cold area. It is permissible to eat in this area. No contaminated clothing is allowed in this room. Correct clothing will include personal clothing or a clean white coat over clean Anti-C clothing. All other rooms are designated as contaminated areas. Anti-C coveralls are the accepted dress for working in these contaminated areas. In the washed clothing area, Anti-C lab coats may be worn over personal clothing.

The personnel at the laundry are protected by a radiation detector above the receiving room door and a CAM in the working area. These rooms are evacuated immediately if either instrument alarms, and then CFA Health Physics is called for advice.

The CFA laundry is also used as an Anti-C change room and personnel decontamination facility for CFA personnel.

3. CF 674 (Sewage Treatment Plant)

Any radioactive material placed in any drain at CFA is processed through the sewage treatment plant located near the laundry. Most of the radioactive waste comes from the laundry (CF 669), although small amounts enter from CF 656 and CF 690. A hazardous area is created at the drying pond into which sewage is dumped from the main plant. The dried sludge or sewage is removed periodically to the burial ground as a routine radioactive shipment. A Safe Work Permit is required whenever this material is handled. Any work done around the trickling filter also requires a Safe Work Permit. Continuous liquid samples from the laundry weir and from the ground waste water are collected by the CFA HPs and sent to CPP for special analysis.

4. CF 687 (Lead Shop)

The lead shop is a small metal building located west of the sewage treatment plant. The building may have a radioactive contamination problem at times since personnel often work with contaminated used lead. The contaminated waste is sent to the burial ground.

5. CF 640 (Machine Shop) and CF 665 (Maintenance Shop)

Two other buildings which may have radioactive material in them from time to time are the machine shop and the big maintenance shop. Radioactive material which the plant machine shops cannot handle is worked on in the more fully equipped CF machine shop. Usually this material is of a low radiation and contamination level. However, each item has to be checked thoroughly when brought in to the machine shop from any area where possible contamination is suspected. Air sampling and routine monitoring procedures are used during the machining of contaminated articles. As in the machine shop, vehicle maintenance shop personnel must sometimes work on vehicles and equipment which are used to haul radioactive material. Such vehicles are surveyed prior to shop maintenance work and, when necessary, are sent to CPP for decontamination.

6. CF 674A (Chemical Engineering Laboratory)

At the south end of CF 674 Warehouse is the Chemical Engineering Laboratory. Here experiments in which radioactive tracers are sometimes used are set up and the data from them later used for processing design at CPP. Film badges, Anti-C clothing, and protective equipment are required in this lab.

7. CF 688 (Technical Services Center)

CF 688 is an area in which irradiated pieces from SPERT are occasionally received. A laser is operated in this building, and approved special work procedures must be followed in its operation.

8. CF 601 (CF Warehouse)

This is the receiving center for radioactive shipments received via commercial carriers on regular working days. These shipments are monitored by CF Health Physics and the proper papers are completed and routed to the proper recipients.

9. CF 656 (Reactor Engineering Laboratory)

Beryllium pieces and some radioactive sources are used by the Reactor Engineering Group at this facility. Handling of beryllium requires special approved work procedures.

The following buildings usually do not have hazards associated with them but are listed and described because of their importance to Idaho Nuclear Health Physicists.

10. Powder Bunkers

East of the laundry is a series of old powder bunkers. In one of these bunkers some radioactive material is stored. Generally, this radioactive material is in small lots which have arrived at the NRTS for burial. These small lots are allowed to accumulate until a truck load is available for disposal or until they become radiation hazards. One bunker is also used intermittently as a low background counting facility by the Nuclear Physics Group. Counting sources are occasionally used here.

11. Gantry - Railyard Area

All incoming or outgoing radioactive rail shipments, including piggy back trucks, must be routed through this area. Necessary paper work must be completed by CF Health Physics. Radioactive shipment casks may be stored in this area for short periods of time.

12. CF 689 (Technical Library)

The library holds most of the technical books, journals, reference works, AEC reports, indexes, abstracts, and other materials needed by scientists and engineers at the NRTS, and can obtain items not available in the NRTS Library, including patents and translations, on reasonably short notice. The Technical Library has interlibrary loan arrangements with several large university libraries, special libraries throughout the United States, AEC's Technical Information Services at Oak Ridge and Washington, and similar libraries at other AEC sites.

13. CF 603 and 690 (AEC Health and Safety Technical Services)

These buildings house the Idaho Operations Office (ID) Health and Safety Division. The Division is divided into seven branches with six in CF 690 and the Medical Branch in CF 603.

a. CF 603 (Dispensary)

Major medical services are available at the dispensary located in CF 603. The dispensary is completely staffed and equipped to offer NRTS contractors services ranging from physical examinations to evaluation and treatment of occupational injuries or minor non-occupational illnesses. The general staff at the dispensary includes industrial physicians, nurses, laboratory and X-ray technicians, and clerical personnel. The dispensary is operated from 8:00 a.m. to 4:30 p.m. daily, Monday through Friday, excluding holidays. An industrial nurse is on duty at the CF Dispensary on night shifts, weekends and holidays. The scope of services available are:

(1) A clinical laboratory for carrying out diagnostic procedures and examinations to evaluate specific occupational exposures. Complete blood counts and urinalysis are done on a periodic basis. Special analyses that may be done as desired include blood determinations for: sugar, uric acid, transaminases, urea nitrogen and carbon monoxide. Bacteriological examinations are done on water samples and cultures from cafeteria inspections.

(2) Physical examinations which include pre-placement, periodic, termination and special exams for disability evaluations, as well as evaluating qualifications for special occupations, and return to work.

(3) X-rays are taken at the time of physical examinations, as special period exams, and for diagnosis of occupational injuries and diseases.

(4) Visual and hearing acuity evaluation tests are given as regularly scheduled or as specially indicated.

(5) Examination, diagnosis and treatment of occupational injuries and diseases and short-term treatment of acute non-occupational illnesses are also given.

(6) Physical therapy treatments are available which include the use of heat, diathermy and ultrasound.

(7) Immunization programs, periodic tetanus immunizations and other special immunization programs occur as needed.

(8) Ambulance services for any emergencies requiring transportation of the patient to nearby communities are provided.

Equipment available includes a clinical laboratory with a diagnostic X-ray department, equipment for diathermy and ultrasonic treatments and minor surgical repairs, an orthorater, an audiometer, an electrocardiograph recorder, an equipped room for emergency care of radioactively contaminated personnel, and ambulances.

b. CF 690 (AEC Health and Safety Technical Services)

(1) Dosimetry Branch

This branch provides services for a complete personnel monitoring of NRTS personnel and the determination and preservation of vital exposure records. Radiation detection devices are provided to all NRTS personnel and visitors for the detection of beta and/or gamma radiation and fast neutrons utilizing film and/or thermoluminescent dosimetry. Wrist badges, finger rings, film pads, and self-reading pocket dosimeters are provided if needed. Assistance in special problems of area monitoring through the use of 5" x 7" and 14" x 17" film are provided as well as pocket-size beta-gamma film, and Nuclear Track Emulsion Type A (NTA) fast neutron film. Personnel metering processes radiation detection film. The results of this dosimetry are data processed and tabulated in report form. Equipment available includes an automatic film badge reader, Photovolt 501-R dosimeter, X-ray machines, thermoluminescent dosimeter reader, and photoluminescent dosimeter reader.

(2) Analytical Chemistry Branch

The laboratory is staffed and equipped to provide chemical or radio-chemical analysis for toxic materials of significance to health and safety. Services available include analysis of environmental samples for naturally occurring radionuclides such as Po-210, U-238, Th-230, Ra-226, and Pa-231; special radiochemical analyses for specific radionuclides such as Pu-239 and Sr-90 in body excreta, water and air; routine urinalyses for radioiodine; in vivo determination of gamma-emitting radionuclides in the human body; analyses for chemically toxic materials such as lead, beryllium, mercury, and thorium of importance to good industrial hygiene practice; professional services and advice in the development or evaluation of analytical procedures or solution of problems related to general chemistry; activation analyses to determine submicrogram quantities of elements; and alpha and gamma spectrometric analyses.

The equipment found in this branch includes alpha, beta and gamma-counting instruments, 400 and 4096-channel pulse height analyzers, ultraviolet and visible spectrophotometers, recording spectrophotometers, fluorophotometers, polaragraph, liquid scintillation counters, and whole-body counters.

(3) Health Physics Branch

The Health Physics Branch develops and administers a program to provide radiation protection for the NRTS and its environs. This includes:

(a) An on-site and off-site monitoring and sampling program of air, water, milk, plants and animals for determination of level and significance of radioactivity in man's environment and food stuffs (data summary furnished in semi-annual reports and upon request).

(b) Emergency and disaster planning for radiological incidents, emergency monitoring, and consultation for the NRTS and its environs. This includes on-site and off-site emergency monitoring, support of operating contractor health physics, and activation and staffing of emergency mobile support facilities for use as a temporary control center at any NRTS facility.

(c) The notification of all organizations at the NRTS of impending or potential involvement in an airborne release of radioactivity from a planned or accidental release.

(d) Health physics coverage, consultation, and surveys for NRTS contractors and AEC-ID Divisions not having their own health physics organization or special equipment. In most cases this service is provided upon request from the interested organization.

(e) The consultation, reviewing, and evaluation on regular and special health problems, such as regulation interpretation, procedures, safety analysis reports, planned environmental releases and special tests.

(f) The establishing of plans, procedures, equipment and coordination of the AEC-ID and NRTS contractors Radiological Assistance Team in event of a radiological incident occurring in Idaho, Montana, Wyoming, Utah, Colorado, or the NRTS.

(g) Consultation, research, recommendations and assistance on biological or radiobiological problems concerning NRTS operations.

(h) Bi-monthly seminars for health physics personnel for exchange of information, coordination of mutual projects and issuance of technical data.

(i) The publication and distribution of semi-annual Environmental Monitoring Report for NRTS and vicinity.

(j) Health physics training and/or lectures, including radiological safety talks for safety meetings.

Equipment available for the use of this branch includes: a road monitor, an aerial monitoring kit, radiological assistance kits, mobile environmental sampler and monitor, a remote controlled portable environmental radiation monitor, a telemetry system for environmental monitoring, and a portable milk monitor.

(4) Instrumentation Branch

This branch provides instrument services to modify and calibrate equipment used for radioactivity measurements and analysis. It also adapts and develops special Health Physics detection and radiation monitoring equipment and systems. The scope of its work includes maintaining, calibrating, and supplying portable radiation survey instrumentation for use by contractors at NRTS; maintaining and calibrating radio-chemical analysis and associated instrumentation; providing calibration for secondary standards of gamma emitting radioisotope sources; providing calibration dosimetry film for beta, gamma, and neutron emitting sources; developing specialized electronic systems; and consulting in the development and evaluation of instrumentation.

(5) Hazards Control Branch

The staff and facilities of this branch are available to support a safety program designed to prevent injury to employees and damage to government or private property. The scope of its services includes: a periodic review of all facilities to locate problem areas and furnish guidance in accordance with AEC codes and standards; consultant services in all special functions including exhaust ventilation and air filtration with special studies on request; functional engineering review in design criteria of new facilities, systems or modifications with interpretation of Federal, State and local codes and standards; arrangements for operator licensing for government motor vehicles; liaison on NRTS vehicle regulations and accident reporting; guidance on site-wide standards for such activities as transportation, storage and use of high explosives, on-site and off-site shipping of radioactive materials, standards of compressed gas cylinders, electrical work on or near NRTS high voltage lines, and work or movements affecting NRTS traffic; consultant services and specialized equipment available for the collection, analysis and evaluation of airborne radioactive and non-radioactive contaminant; quarterly seminars for NRTS safety personnel for exchange of information, coordination of mutual projects, and issuance of technical data for individual operations programs; review and certification of NRTS contractors' manhour records for recognition under State and/or AEC Safety Award Plan; NRTS distribution of NRTS quarterly summaries on health and safety experience, AEC issuances on serious accidents, safety and fire protection, health and safety information and accident experience and award plan, NRTS information bulletins and special announcements; issuance of biannual inventory register of contractor and ID equipment available for emergency use. This listing includes such equipment as: radios, cots, respiratory equipment, field emergency trailers, HP portable instruments, protective clothing, food rations and vehicles with towing devices. Engineers are available to conduct and compile annual appraisal reports in health physics, industrial hygiene, fire engineering and industrial safety.

(6) Waste Management Branch

Waste Management reviews and evaluates regular and special problems such as regulative interpretation, procedures, and coordination of action between contractors; environmental research in disposal of radioactive wastes; preparation of disposal criteria, and review of design for waste handling systems.

c. CF 690 (Institute for Atmospheric Sciences)

CF 690 also houses the Institute for Atmospheric Sciences which has been established as an adjunct to the Idaho Operations Office (ID) to assist in defining the atmospheric behavior of radioactive and chemical effluent from nuclear facilities and to provide other meteorological services to AEC and NRTS contractors. Its meteorological facilities and staff offer a complete service range to include severe weather warnings, data associated with actual operations of contractor's facilities and special services. The work of this group includes:

(1) Observations and forecasts for specially planned radioactive and chemical effluent atmospheric releases or high risk experiments which shall include, but are not limited to, radioactive cloud trajectory and concentrations predictions.

(2) Daily forecasts during normal five-day work week to include certain meteorological elements such as wind speed and direction,

temperature and precipitation. Special warnings are issued when requested for blizzards, low temperatures, high winds, and electrical storms.

(3) Daily atmospheric diffusion forecasts to meet needs of reactor operations groups.

(4) Source term calculations based on environmental monitoring results following planned or accidental atmospheric releases of radioactive or toxic materials.

(5) Micro-meteorological studies for advanced planning.

(6) Review and evaluation of safety analysis reports on new and proposed NRTS installations.

(7) Consultation services on reactor siting and meteorological instrumentation use and emplacement.

(8) Records and climatological reports for use on advance planning and reactor siting. Climatological statistics include temperatures from seven feet below ground to 5,000 feet above the surface, the relative humidity, wind direction and speed, and precipitation both at surface and heights above ground.

(9) Special meteorological observations, forecasts, and climatological studies as required for current or future work and facilities.

The facilities available include: a 250 foot tower at CFA, a 200 foot tower at the Test Area North (TAN), a 240 foot tower at the Experimental Breeder Reactor No. 2 (EBR-II), a Grid No. 3, 200 foot tower near the Test Reactor Area (TRA), and various small weather stations with limited climatological information.

B. Associated Areas

1. Burial Ground

The NRTS burial ground, 88 acres in size, is located in the southwest part of the NRTS and is immediately available to approved licensees, Federal agencies, and AEC facilities for disposal of solid, packaged radioactive wastes of the type associated with laboratory and research activities and routine reactor operations. This may include broken glassware, paper smears, rags, ashes, animal carcasses, laboratory paraphernalia, etc. The wastes are usually solid substances consisting of or contaminated with radiation source, special nuclear, or by-product materials. Radioactive materials not so contaminated, such as radium and accelerator-produced isotopes, do not fall within the scope of this burial service. (Provisions have been made by the AEC for their disposal.)

Large pits and trenches are used to dispose of the waste. Low level waste is buried in shallow trenches and pits with a maximum depth of approximately four feet. High activity waste is buried in deeper trenches and pits with a maximum depth of approximately fifteen feet. A CF HP is present whenever waste is being buried.

2. ARA Hot Cell

The hot cell in the Auxiliary Reactor Experimental Area (ARA) has all the facilities related to an operation of this type of work. Although the SL-1 area is operated by another AEC contractor, the Idaho Nuclear Corporation CF Health Physics Group receives occasional calls and requests for surveys from people working in this area.

3. Site Vehicle Survey

This program is a large time consuming job. There are approximately nine hundred vehicles plus NRTS buses involved in the survey. The buses are surveyed semi-annually for radiation hazards by the CF Health Physics Group. All other NRTS vehicles are surveyed annually for radiation hazards. Reports are submitted to management on the results of the surveys.

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CHAPTER VII

TEST AREA NORTH

A. Introduction

The Test Area North (TAN) is located about 26 miles north of Central Facilities and is composed of six separate facilities (see Figure 55). These are: Loss of Fluid Test (LOFT), Low Power Test (LPT), Flight Engine Test (FET), Initial Engine Test (IET), Experimental Beryllium Oxide Reactor (EBOR), and Technical Support Facilities (TSF).

1. Loss of Fluid Test (LOFT)

The LOFT facility was constructed to investigate the consequences of a loss of coolant from a pressurized water power reactor. It is operated and controlled by Phillips Petroleum Company and is located adjacent to the FET Building.

2. Low Power Test (LPT)

The LPT houses the General Electric Company's reactor facilities and is located adjacent to EBOR.

3. Flight Engine Test (FET) (Bldg. 629)

The FET was originally constructed to serve as a hanger for a huge nuclear powered airplane. It is a large building, 240 feet by 320 feet, with a maximum height of 99 feet. It is now used as a clean storage area, consequently health physics work in this area usually consists of checking for possible contamination of material going in and out of the building.

4. Initial Engine Test (IET)

The IET area was originally used for several SNAP 2/10A Aerospace reactor tests. It is now a shutdown area and is used for the storage of some radioactive items. This facility is located 1-1/2 miles north of the TSF within a barbed-wire exclusion area. The exclusion area, or test area, restricts access to within approximately one mile of the facility. The immediate IET area is surrounded by a security fence with a guard house and consists of a Test Cell, Control and Equipment Building, and several other auxiliary facilities. Included are fuel pumping, storage tank, exhaust stack sampling, and chlorination buildings. The storage tank building was used as a liquid nitrogen unloading and vaporizing station. Access to the area is provided by means of a four-rail track system and an automobile roadway from TSF.

5. Experimental Beryllium Oxide Reactor (EBOR)

The EBOR, originally set up to test the concept of a beryllium oxide reactor, was operated by the General Atomics Company. It is now in a "moth-ball" state under Idaho Nuclear Corporation control.

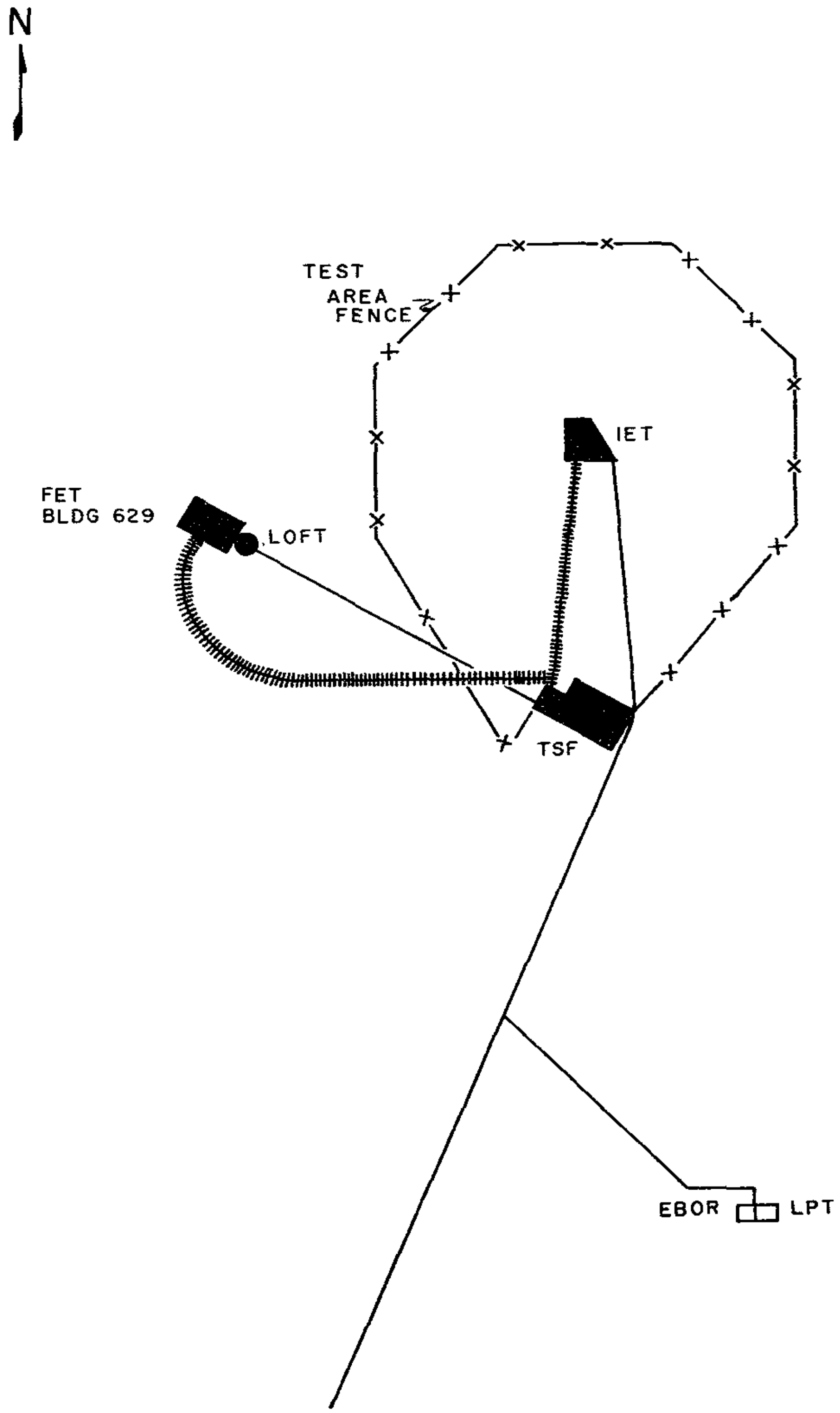

Figure 55

Vicinity Map of TAN Area

6. Technical Support Facilities (TSF)

The TSF area, which is comprised of office space, utilities, a hot shop, hot cells, shop areas and decontamination facilities, is mainly operated by Idaho Nuclear Corporation. Health and Safety responsibilities within the fence belong to Idaho Nuclear Corporation with the exception of certain buildings or areas which have been assigned to other operating contractors. Examples of this are Buildings 606 and 609 which are assigned to Phillips Petroleum Company and Building 604 which is assigned to General Electric.

Services such as maintenance, hot shop and cell work, decontamination work, and health physics monitoring are available from Idaho Nuclear Corporation to any contractors in this area if they desire to use them.

a. Hot Shop

(1) Construction

The hot shop is an area 160 ft. long x 51 ft. wide x 67-1/2 ft. high.(see Figures 56, 57, and 58). The east end of the hot shop is partitioned to form the special equipment services cubicle. This cubicle is used for repairing the overhead manipulator and overhead crane when the hot shop contains radioactive materials.

The west wall contains the locomotive and rolling stock entrance door. It is a sliding, bi-parting concrete floor with a staggered joint. Movement of this door is accomplished by electric motors located outside the hot shop and controlled from the control console.

A personnel labyrinth is provided in the southwest corner for access to the hot shop. A monitoring and change room is located just outside this labyrinth.

The hot shop floor is designed to sustain a uniformly distributed load of 250 lb./sq. ft. over the entire floor area. It is permissible to position a load equally distributed on four legs not to exceed 25,000 lbs. per leg.

(2) Turntables

Two turntables which are essentially flush with the floor have been provided to rotate radioactive devices so that work may be viewed from the hot shop windows. Remote control allows rotation and automatic selective indexing of the turntables.

Each turntable is capable of supporting a 60 ton load. The outer edge of the turntable is provided with a stainless steel skirt which revolves in a water-filled trench, providing an airtight seal between the turntable pit and the hot shop.

Two control stations are provided for each turntable and are located at windows adjacent to the turntable in the upper and lower operating galleries. Controls for directional rotation, speed, and indexing are located at each control station.

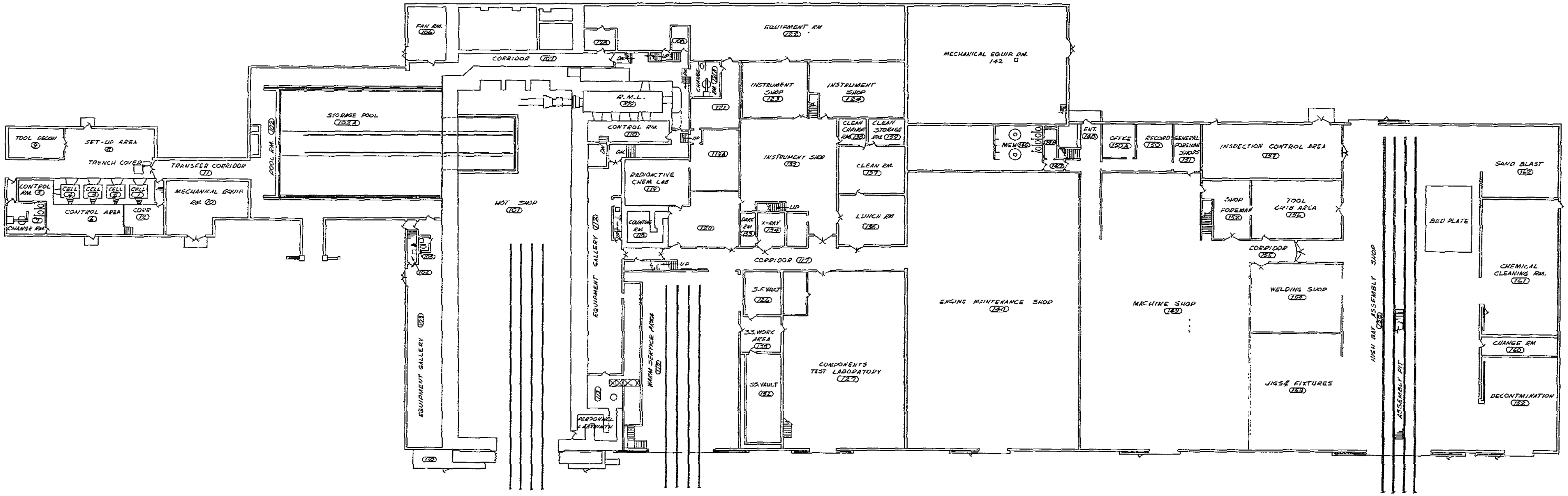

Figure 56

TAN Building 607
First Floor Plan

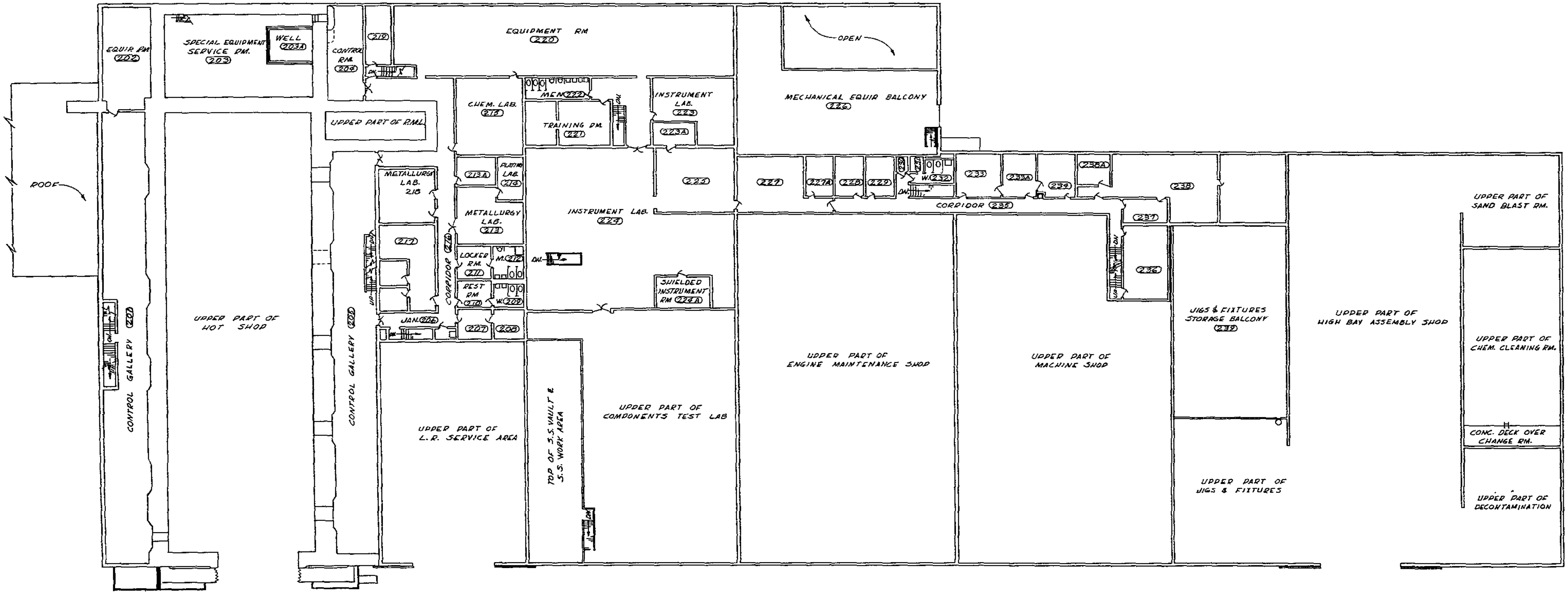

Figure 57

TAN Building 607
Second Floor Plan

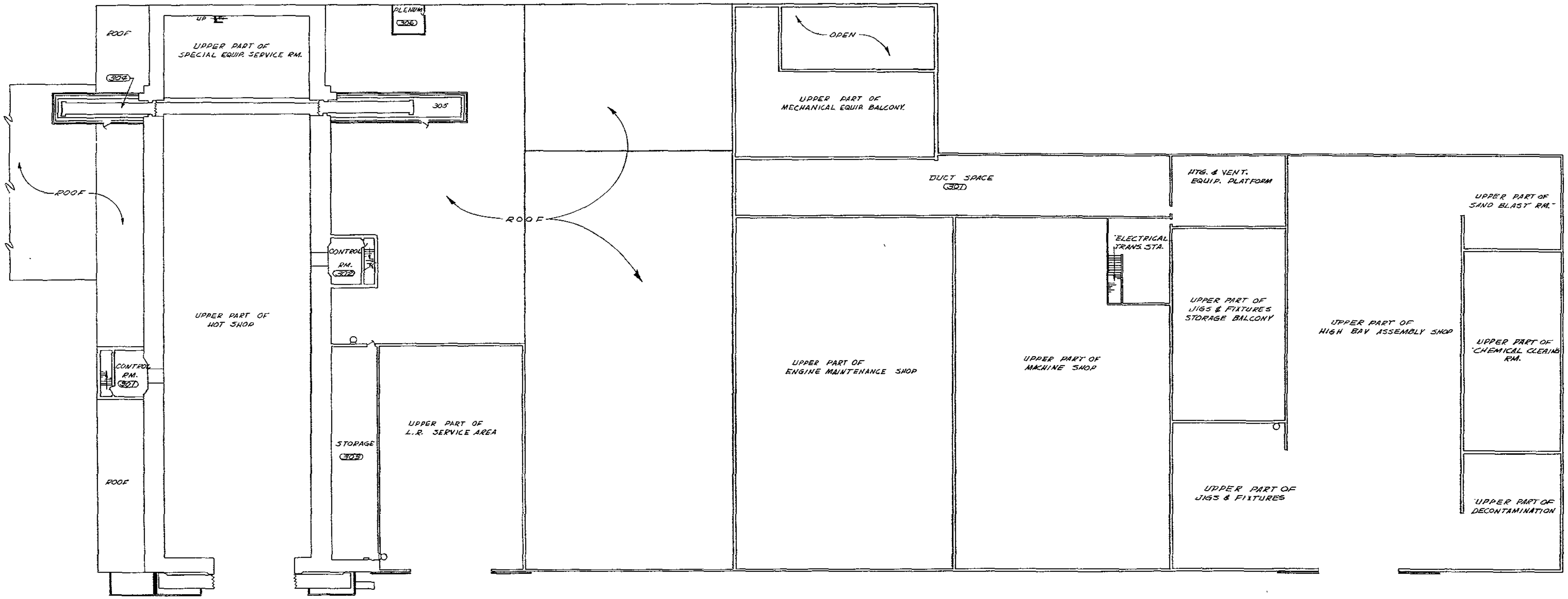

Figure 58

TAN Building 607
Third Floor Plan

(3) 100 Ton Crane

The hot shop heavy crane is a 100 ton overhead, single dolly, double-hoist crane especially equipped and adapted for operation by remote control. It is used to lift, hold, and transport heavy assemblies, tools, and fixtures and to retrieve other types of handling equipment should they become inoperative.

Should electrical failure occur to the hoist mechanism, the hazardous load may be lowered by an auxiliary electrically operated hydraulic system. The hydraulic pressure can be directed to release both the mechanical load brakes and the solenoid holding brakes on both the main and auxiliary hoists.

The control stations for the heavy crane are located at the hot shop windows and are interlocked so that only one station may have control of the crane at a given time and control cannot be "stolen" from the operating station by a standby station. Each station contains all controls necessary for the remote operation of the crane.

(4) Manipulators

The remote handling equipment in the hot cell is of the general purpose type. This equipment has been engineered to service a variety of "hot" mechanisms with the greatest possible versatility, and to handle future designs with a minimum of modification.

The hot shop contains two wall-type manipulators on each long wall and a heavy-duty overhead manipulator, all of which can be coordinated to work together. The heavy-duty overhead manipulator also serves as a crane follower.

(5) Control Console

The dispatcher's control console provides a central unit for remote operation of the outdoor turntable, railroad signal, hot shop door, outdoor viewing, communications control for the locomotive, and control of emergency power. This unit is divided into three basic sections.

(a) Selective Power Controls

Provision is made for controlling the power supply to the various electrical equipment in the hot shop building during emergency power operation. Selected hot shop equipment may be operated to the capacity of the emergency power supply. An ammeter is provided on the selective power panel for the dispatcher's guidance as to the load on the system.

(b) Communication System

A communications center for the remote facilities operation is provided at the dispatcher's control console. Through this radio system, the operator is able to communicate with the IET control room and with the shielded locomotive operator.

(c) Railroad System Control

Since the dispatcher will have control of the shielded locomotive operations, the console contains many controls for the railroad system. Miscellaneous controls necessary for the locomotive system are found on the console. They are hot shop door controls, alarm system controls, turntable rail sanding controls, and turntable flood light controls.

Television monitors and controls on the console allow the dispatcher to observe the movements of the locomotive as it approaches the turntable and the hot shop. One camera is mounted near the locomotive turntable and the other in front of the hot shop.

The indicators and controls necessary for the operation of the railway turntables are displayed in a pictorial layout on the control console. A selsyn indicating system is used to determine when the turntable and a particular track are in alignment. Block signal lights indicate the approach of the locomotive within a 100 ft. distance of the turntable periphery.

(6) Drain System

There are six drains in the hot shop and two in the special equipment services cubicle for contaminated liquid waste. The northwest corner drain and the one near the personnel labyrinth connect to a 6 in. stainless steel pipe which goes to the Liquid Waste Disposal Building 616. The drains in the northeast corner, the end of the drain trench, and the pit drain and gutter drain from the two turntables, connect outside the hot shop to a 6 in. stainless steel pipe which also goes to Disposal Building 616. The two 6 in. drain lines leading from the hot shop connect to a common sump. The waste is then pumped to three 10,000 gallon storage tanks. From these tanks, the waste is sent through an evaporator for concentration, and then disposed by storage or discharge to a disposal well.

(7) Heating and Ventilating

The heating and ventilating system for the hot shop is integral with that for the warm services area and RML. Under ordinary circumstances, fresh outside air is routed through a blower into the warm services area. The warm services area air is exhausted through three exhaust openings into a duct system by a 32,700 cfm exhaust blower to the intake of the hot shop supply system. The duct downstream of the 32,700 cfm blower has dampers and a gooseneck opening to the outside. By closing the duct damper and opening the gooseneck damper, an emergency negative pressure of 1/8 in. of water can be provided in the warm services area.

The hot shop supply system has an outside opening which pulls 15,420 to 41,420 cfm of fresh air into the system. The air from the outside and the air from the warm services area then goes through a filter, steam coil, damper, and air washer to a 41,420 cfm supply blower. The air supply then passes through a steam reheat coil and branches to the hot shop, the special equipment services room, and the RML. Exhaust air is discharged to the stack.

Air pressures are maintained at a negative 1/8 in. of water pressure in the warm services area and a negative 1/4 in. of water pressure in the hot shop, RML, and the special equipment services room.

(8) Fire Protection

Fire protection is provided in the hot shop by a fog system in the ceiling. This is a 4-zone system, with three zones in the hot shop proper and one zone in the special equipment services cubicle. Each zone operates independently by either automatic or manual action. All hot shop fire-water systems will be blocked off any time a reactor is in the shop.

(9) Services

Electrical and fluid services are brought into the hot shop on pedestals spaced along the walls of the hot shop. These services are remotely controlled at the hot shop windows where provisions are made for "on-off" switching, pressure regulation, and in some cases, flow regulation.

The service pedestals provide the following services: air, oxygen, acetylene, telephone, power, demineralized water, raw water, shield water, crane release, torch ignition, intercom system, television outlet, and camera shelf.

b. Special Services Equipment Area

The remote handling equipment in the hot shop has been so designed that maintenance of this equipment can be performed with a minimum of personnel contact. A special equipment services cubicle has been provided at the rear of the hot shop for maintenance of the overhead manipulator, overhead crane, and the General Mills manipulators. This service cubicle is provided with sliding shielding doors so that it may be shielded from the hot shop. The overhead manipulator and overhead crane may be brought to the services cubicle, decontaminated, and maintained by contact method. A special fixture has been provided so that the General Mills wall manipulators may be remotely removed from the track and boom system and transported by either the overhead manipulator or the overhead crane to the service cubicle.

c. Radioactive Materials Laboratory

The radioactive materials laboratory (RML) is located adjacent to the southeast corner of the hot shop. It is equipped and used for remote inspection, cutting, and other operations of a more delicate nature.

The RML periscope is provided for the close inspection of objects in the inspection cubicle. Objects under this periscope may be viewed with magnifications of 1X, 3X, and 9.6X powers and may be photographed by use of a camera attached to the periscope.

This area is serviced by four Model 8 master-slave manipulators, two Argonne #6 manipulators, and two General Mills type manipulators. Each master-slave manipulator services only a small area directly in front of its mounting window location, but the bridge mounted General Mills manipulators service the entire cubicle. A 3 ft. extension hand has been provided to increase the work volume and usefulness of the General Mills manipulator.

The inspection cubicle cutting equipment is remotely operated Elox arc cutting equipment which has been provided for the remote cutting of small sections of radioactive material under controlled conditions to minimize the spread of contamination in the inspection cubicle.

Contact maintenance has been assumed possible in the case of the RML equipment. The design of the inspection cubicle and its equipment is based on the assumption that radioactive materials may be removed from the room, the room decontaminated, and contact maintenance performed. Acid resistant materials have been used in the construction of this equipment to facilitate decontamination.

The RML has two floor drains with removable stainless steel screens and sediment baskets. These drains are used as contaminated acid drains and are 3 in. stainless steel pipe. Contaminated acid can be drained to a sump where it can be neutralized before disposal to the three 10,000 gallon tanks located at Building 616.

The following services are furnished to the RML: acid, high pressure air, vacuum sampling line, raw water, mask air, demineralized water, and instrument air.

The fire protection system for the RML consists of six 100 lb. CO_2 cylinders manifolded to four discharge nozzles in the RML ceiling. This system is automatic or manual with flow limited to 1950 cfm.

d. Storage Pool Area

A storage pool area located adjacent to the hot shop is used for transfer of material to and from the hot shop.

The storage pool area has a standard 15 ton, single trolley, single hoist, bridge crane for transfer of material within the storage pool area. The power to the crane is on the emergency power circuit and can therefore be controlled from the dispatcher's console. Normally it is controlled from a push-button pendant station on the trolley.

e. Hot Cells

The hot cell facility, consisting of four hot cells and miscellaneous work areas, was designed and built to perform post-irradiation examination of reactor fuel and mechanical components. The cell working space is divided into four equal areas, the type and degree of contamination that can be handled in each being slightly different.

High density concrete was used in the walls with normal density concrete used for the ceilings. The high density concrete walls between the cells reduces the maximum radiation contribution from one cell to another.

The change room is located along the only passage way from the contaminated area to the clean area. Hand-wash fountains and pass-through showers are available for personnel decontamination.

An intercom system is used as a means of communication during installation and checkout of equipment and as a sound monitor during operations. A second intercom connects the control and setup areas with the remainder of the building.

f. Auxiliary Facilities

Also housed in TAN-607 are the following facilities: decontamination room, sand blast room, chemical cleaning room, storage area, components test laboratory, instrument and control laboratory, clean area, inspection and control area, high-bay assembly area, maintenance shop, machine shop, source and special materials vault, welding shop, warm-services area, and auxiliary facilities (locker room, shower area, etc.).

g. Rolling Stock

A shielded locomotive, which is a personnel carrier and prime mover to be used in the hot radiation field of the test area, is housed and maintained in the TSF area.

Water and lead shielding are provided for the cab to permit transporting of personnel. Entrance to the shielded cab can be made through a retractable hatch in the bottom of the cab. Operator stations are provided in front of glass-liquid windows at each end of the cab to allow the operator to view the track. Because of the somewhat limited vision from within, and because of the necessity of foolproof operations of the locomotive, the operator is provided two-way radio contact with the dispatcher in the hot shop. A signal light system at the railway turntable and a guidepost system along the tracks is also provided.

h. Liquid Waste Treatment Building 616

The Waste Concentration Building houses facilities to receive, filter, neutralize, and dispose of contaminated liquid waste originating in TAN 607 and the IET. The plant has a rated capacity of 200 gallons per hour. Liquid waste from these areas is first stored in three 10,000 gallon underground hold-up tanks. After some of the liquid portion is driven off, the remaining effluent, in the form of sludge, is discharged to two 50,000 gallon liquid waste holding tanks located underground near the southwest corner of the TSF area.

i. Health Physics Responsibilities at TSF

The majority of the TSF health physics jobs originate with the TAN 607 building. Two major areas contribute to these jobs, the hot shop complex and the decontamination facility.

The hot shop complex consists of the large hot shop, the adjoining RML, and the HCA. Health Physics personnel are called upon to monitor the materials that are continually being loaded or discharged from the cells. In addition, as the cells are entered for decontamination purposes, health physics protective measures, i.e., Anti-C clothing, respirators, film badges, and dosimeters, are employed to insure that no individual receives any exposure in excess of RPG limits. The doors to the large hot shop are controlled from a control panel on the second floor. Before entry can be made into the cell, a telephone call must be made to the operator in charge. This call should be made by an HP or the person calling should assure the operator that an HP is present. The hot shop is so large that a variety of miscellaneous radioactive items may be present; therefore, it is difficult to determine a general radiation body field. A thorough survey should be made each time the HP accompanies anyone into the cell. A highly radioactive item may have been repositioned without the HP being aware of its new location.

The RML is not entered as often as the Hot Shop. When the cell is down for repairs the majority of known radioactive items are removed through an access door to the Hot Shop. Contamination is a major problem and proper respiratory equipment should be worn until an air sample can be pulled and the hazards evaluated.

These cells constitute major sources of contamination so the HP should use precautionary measures to contain it.

The decontamination facility is the second major area of contamination, although not the problem the Hot Cells are. This decontamination facility is designed to receive contaminated items ranging in size from small hand tools to casks weighing several tons. This facility is operated by health physics personnel and is located in the southern-most wing of the TAN 607 Building. The facilities feature four separate types of cleaning areas, including: decontamination, chemical cleaning, vapor degreasing, and sand blasting. Each of these cleaning areas perform a distinct type of decontamination cleaning, but coupled together the areas are capable of performing any type of cleaning work. The decontamination technicians wear protective clothing when working in the area. The operator of the sand blaster is clothed in protective clothing and wears a full face respirator connected to a fresh air-line. A laboratory counter is nearby to aid the HP in the evaluation of the progress of the decontamination work. A CAM is located outside of the decontamination room but a sniffer hose monitors the working area inside. A warning light that is mounted inside the decontamination room alerts personnel of increased activity as indicated by the CAM.

Criticality hazards are present in two vaults that are located behind the HP field office and in the canal storage area to the north of the Hot Shop. Nuclear fuel is stored in the vaults under strict security and criticality regulations. The plant manager has the keys and controls the quantity of fissile material that can be stored here, but the HP should be aware of the potential problem. Likewise, standard practices are written on the storage of fuel in the canal, but the HP should see that these procedures are adhered to.

The TAN 607 building also has an X-ray machine which can create a radiation hazard in the adjacent hallway. Traffic is alerted in the hallway by a sign placed on a stand calling attention to the operation of the X-ray machine. A red warning light on the outside of the X-ray room automatically comes on when the machine is in operation, and an HP monitors the operation with a cutie pie or comparable instrument.

Eating areas are restricted to locations where contamination is unlikely to be present. Each applicable area has a sign designating it as an eating area. Buildings 601, 602, and 603 are clean areas and are surveyed routinely by Idaho Nuclear Corporation Health Physics.

In prior years, testing of nuclear equipment in the atmosphere necessitated the use of CAMs on the outside of buildings. Three of these CAMs are still in operation and serve as background checks and backup to the CAMs located inside of the buildings. These CAMs are checked on a routine basis for sensitivity.

Several outside areas have to be controlled because of the residual contamination from the SL-1 and ANP projects. The Radioactive Parts Service and Storage Area (RP SSA), Buildings 647 and 648, is one area where the HP should be extremely cautious because of the sundry contaminated and radioactive items that are stored in this fenced enclosure. Radioactive materials are stored behind HP ribbons which, due to weather conditions, may blow down. The HPs are required to keep the ribbons and tags up-to-date.

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2. *Ibid*, pp. 21-22.

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